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# THESIS

## AN EXAMINATION OF HIGH QUALITY ENLISTEES ON A RECRUITING DISTRICT LEVEL

by

Ross Edward Irlam

June 1984

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| Thesis Advisors: | G.W. Thomas<br>Ed. Mc Kenzie |

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# An Examination of High Quality Enlistees on a Recruiting District Level

by

Ross Edward Irlam
Lieutenant Commander, United States Navy
B.A., Western Illinois University 1970

Submitted in partial fulfillment of the
requirements for the degree of

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## ABSTRACT

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# I. INTRODUCTION

## A. PROBLEM

Current military policy includes an expansion of the Navy from the present level of approximately 500 ships to approximately 600 ships by the end of the decade. This expansion is being conducted at a time when the primary recruiting pool, 17 - 21 year old males, is declining. There are two avenues which must be pursued to prevent a short fall in personnel to man the expanding fleet. First, the Navy must retain high quality personnel and secondly, the Navy must recruit sufficient numbers of high quality personnel to replace attritions and simultaneously meet ever increasing manpower requirements.

It is not enough just to recruit warm bodies to fill vacancies. The ability of the American serviceman to adequately operate and maintain equipment of increasing sophistication has been widely debated in Congress and the press. Stories abound of the expected deterioration of equipment readiness during periods of increased tensions in the event of the loss of civilian personnel. To maintain an effective force, the Armed Services must be able to operate and maintain its' equipment independent of noncombatant civilian technicians. In order to achieve this goal, personnel with the ability to learn the operation and maintenance of ever more sophisticated equipment must be obtained and retained.

One avenue proposed to alleviate a manpower shortfall is an expanded role for women in the Armed Forces. This would seem, on the surface, to be a viable solution to the problem since women have been historically less expensive to recruit and retain than men of comparable quality [Ref. 1]. However, the Navy is precluded from taking full advantage of this source of manpower due to public law precluding the permanent assignment of women to combatant ships. This requires focusing the recruiting effort towards high quality men. The definition of "high quality" has been widely debated. For the purposes of this study, "high quality" will be defined as high school graduates in Mental Groups I through III upper as measured by test scores on the Armed Forces Vocational Battery of tests (ASVAB).

## B. FOCUS

This thesis is concerned with developing a model to forecast the number of high quality nonprior service males signing contracts on the recruiting district level. The dependent variable is net contracts signed: CNTRCTS. Values of this variable are determined by subtracting Delayed Entry Program (DEP) attrites during the month of attrition from contracts signed during the same month.

Three approaches to forecasting CNTRCTS are taken. First, the Box-Jenkins methodology is applied to a monthly time series of the net number of nonprior service high school graduate males signing contracts in the Albuquerque New Mexico recruiting district during the period October 1978 to September 1983 (60 data points). This methodology is explained in detail in Appendix A. The second approach utilizes "best fit" lagged variables in a block regression format to provide a causal model using economic data, the number of production recruiters and military/civilian pay ratio as explanitory variables. The third procedure combines the causal model and the Box-Jenkins methodology in a mixed time series/causal model to attempt to provide more accurate forecasts.

## C. THE ENVIRONMENT

This thesis will limit the scope of study to a single recruiting district. It is hypothesized that better estimates of the effects of changing economic factors and the effects of the variation in the number of production recruiters will be obtained at this level than on a national scope. During any change in the general trends of the nation's economy, local conditions are apt to vary considerably from recruiting area to recruiting area. It may be that the economic trends in a particular recruiting district are in direct opposition to those on the national level. While goals and quotas are specified at a national level, recruitment of individuals occurs at the district level. The Navy Recruiting Command (NRC) allocates a fraction of the national quota to each of the Navy Recruiting Areas (NRA). The six NRA's in turn allocate fractions of their quota to each Navy Recruiting District (NRD) within the area. Historical enlistment rates and differences in regional population are primary determinants of quota allocation, although economic and demographic factors are also taken into consideration [Ref. 2]. Information obtained from a regional study, through a better understanding of the interacting processes, may be of more practical value in allocating recruiting resources for maximum benefit, and in more equitably assigning recruiting goals.

The recruiting district chosen for study is the Albuquerque, New Mexico recruiting district. This district was chosen at random from the 44 recruiting districts nation wide. This district encompasses the entire state of New Mexico, the panhandles of Texas and Oklahoma as well as seven counties in south western Kansas. In general this district experienced an increasing work force, increasing unemployment and a significant variation in the number of production recruiters during the period of study. Appendix B contains the time series plots of the variables.

Background demographic factors for the area that are of interest are as follows. The average per capita income for the state of New Mexico in 1979 was $ 6119, 43 rd in the nation. The population in 1980 was 75% White, 2% Black and 8% American Indian. 37% of the population was of Spanish origin. 13% of the population was between 18 and 24 years old [Ref. 3].

# II. A REVIEW OF THE LITERATURE ON MILITARY SUPPLY

## A. DARLING (1979)

In his thesis on the supply of first term enlistees to the United States Marine Corps, Darling, [Ref. 4], provides a detailed review of the literature on the supply models developed from the Gates Commission (November 1970) to the publication of his thesis (March 1979). The following review will cover the pertinent literature commencing with Darling's work.

Darling used two distinct analytical techniques to develop models in order to forecast monthly first term enlistees in the United States Marine Corps. A multiple regression model was derived based on it's compatibility with his theory of occupational choice, the intuitive appeal of certain explanatory variables, the past literature of manpower supply and the statistical significance of each variables impact on monthly enlistments. The data base utilized was a time series of monthly enlistments spanning the period from July 1973 to June 1978.

For his multiple regression model, Darling chose as the dependent variable; monthly observations of the ratio of male nonprior service high school graduates enlisting in the regular Marine Corps to male high school graduates, aged 16 to 24, not enrolled in college (S). Darling chose as the independent variables: (1) Civilian - Military pay ratio (CMPR), (2) a deseasonalized estimate of the national unemployment rate for persons aged 16 to 19 (UNEM), (3) the monthly number of qualified leads obtained from postcards which were included in the national printed media advertisements (LEADS), (4) a dummy variable to correct for the abnormally large number of enlistments in the month of December 1976 to take advantage of the expiring GI Bill (DJ) and (5) the number of Marine recruiters on duty each month (EFFREC). His initial hypothesis was that the number of monthly enlistments is dependent on the above independent variables in the functional form of a logistic model:

$$S= \left(1+\exp\left[-(B_0+B_1 CMPR + B_2 EFFREC + B_3 UNEM + B_4 LEADS + B_5 DJ + a)\right]\right)^{-1}$$

Only those regular enlistments of male high school graduates in the top two mental groups were considered to ensure that the observed number of monthly enlistments was not restricted by Marine Corps policy (demand driven) and was therefore an accurate representation of points on the supply curve. All the independent variables listed above (except DJ) were lagged from one to six months and regressions were run to discover those variables that significantly contributed to the pattern of enlistments and to ascertain the approximate delay in the impact on contracts signed of a change in the value of one of the variables. The final regression equation selected was based on the intuitive appeal of the regression equation and the statistical significance of the results. The best fit equation was determined to be:

$$LN\left(\frac{S}{1-S}\right) = -2.669 - 5.647\ CMPR5 + 1.00\ UNEM + 0.672\ DJ + a$$

where:

S = the enlistment rate

CMPR5 = civilian - military pay ratio lagged five months

UNEM = unemployment with no lag

DJ = dummy variable for December, 1976

a = random error.

all independent variables were reported to be significant at the 10% level with a coefficient of determination, R-squared value, of .42. Of significance is the exclusion of the variable representing recruiters. Darling reported that when this variable was forced into the regression equation, its' regression coefficient was never statistically different from zero. Darling also reported a Durbin-Watson statistic of 1.08, indicating a positive serial correlation among the residuals. He felt that this was probably due to the lack of an attempt to explain the seasonal nature of Marine Corps enlistments to this point in his study. In an attempt to correct this problem, the Box-Jenkins methodology was applied.

Darling utilized the data from the multiple regression model in a Box-Jenkins procedure to arrive at a final model:

$$Y_T = .804251Y_{T-1} + Y_{T-12} - .804251Y_{T-13} - 7.095902 + e_T - .478727e_{T-12}$$

Where Y was the number of male high school graduates in mental groups I and II who enlisted in month t and e was the error term. Utilizing this model, he conducted two forecasts with varying degrees of success. The first forecast conducted incorporated the abnormally high enlistment month of December 1976. This resulted in the distortion of the forecasts. For the second forecast, not incorporating December 1976, the pattern of enlistments was well represented by the model.

Darling concluded his thesis by combining the two methods in applying Box-Jenkins to the residuals of the multiple regression analysis as if they were an original time series. He then used this combined model to forecast Marine enlistments with a greater degree of accuracy than with either model individually.

## B. DALE AND GILROY (1983)

Dale and Gilroy in two studies of the economic determinants of military enlistment rates [Ref. 5 and 6] utilized a regression equation to forecast enlistment rates of male high school graduates in mental groups I through III upper for the Army. The dependent variable was total contract signers divided by the relevant civilian population of 16 to 19 year olds. Their basic equations were estimated with a linear functional form using generalized least squares, correcting for the presence of first order autocorrelation. Their equation for all males was:

$$\begin{aligned} A/P = {} & -1968.90 + 16.39\ \text{UM} + 7.77\ \text{UM-2} + 4.59\ \text{UM-4} \\ & + 40.89\ \text{W4} + 313.07\ \text{BILL} + 408.40\ \text{VEAP} \\ & + 6.26\ \text{KICK} + 84.65\ \text{Q3} \\ & + 819.73\ \text{GI} + 148.38\ \text{TARGET} - 0.00\ \text{RECRTR} \end{aligned}$$

where:

A = Army accessions plus DEP of male NPS high school grads in mental groups I through III upper.

P = Revelant male population of 16 to 19 year olds.

UM = Current unemployment rate of 16 to 19 year olds.

UM-2 = UM lagged two months.

UM-4 = UM lagged four months.

W4 = Ratio of first year basic military compensation to average weekly earnings in the private sector, with a four month lead.

GI = Dummy variable = 1 in December, 1976 when

GI Bill expired, and =0 everywhere else.

BIII = Maximum monthly benefit for a GI bill beneficiary without dependents, deflated by the consumer price index. Variable is set to zero after December, 1976.

VEAP = Maximum monthly benefit for a VEAP beneficiary without dependents , deflated by the consumer price index. Variable is set to zero before January, 1977.

Kick = Maximum value of kicker payment (offered only to Army enlistees who entered critical specialties in combat arms) deflated by the consumer price index.

TARGET= Binary variable = 1 from November, 1979 to August 1981 when high school grads were specifically targeted, and 0 elsewhere.

Q3 = Seasonal dummy variable = 1 in July, August and September, and = 0 elsewhere.

RECRTR= Number of production recruiters.

As with Darling's work, of some interest is the insignificant statistical results for the number of production recruiters. Dale and Gilroy do not conclude that recruiters are unimportant, but that the variation in the number of production recruiters has not been large enough to show any correlation with enlistment rates. They include the variable "TARGET" as a proxy for the recruiters' efforts.

In their study they determined that a rise in the unemployment rate of 16 to 19 year old males led to a significant increase in Army enlistments and that a drop in national unemployment from ten percent to nine percent would cause Army enlistments of male nonprior service high school graduates to fall by about 8.8 percent. They project that the elasticity of total Army enlistment rates with respect to relative pay is in the range of .9 to 1.7 percent for mental groups I to III upper. They concluded that a relative decrease in military pay of one percent in relation to civilian pay would cause enlistment rates to fall substantially. Also, they found a statistically significant increase in the rate of enlistments during the period November 1979 to Augtst 1981 when the Army was committed to increasing the percentage of high school graduates. Finally, they concluded that educational benefits are very important to many high school graduates, including those in the highest mental groups.

## C. GOLDBERG AND GREENSTON (1983)

Goldberg and Greenston [Ref. 7] provided a progress report on on-going time series cross-sectional analysis research into the determinants of high quality enlisted supply. They contended that utilizing a regional data base rather than a national approach permited more accurate modeling of demographic factors and produced better estimates of the effects of changing labor market conditions. They asserted that by utilizing a regional approach, a greater capability to optimize the allocation of goals, recruiters and advertising is achieved.

A regression analysis was used to estimate the effects of supply factors on the number of contracts signed by nonprior service male high school graduates for each service. Annual data for the time period 1976T to 1982, using 43 Navy recruiting districts as units of observation, was evaluated. Seperate regression models were developed for mental groups I to III upper and mental group III lower.

They assumed the supply of HSDG contracts in a recruiting district to be a log-linear function of supply factors in the form of:

$$\begin{aligned}\text{Ln } H = {} & 1.51 + .75\ \text{LRPAY} + .05\ \text{RUNEM} + .15\ \text{LAVG} \\ & - 0.26\ \text{VEAP} + 0.43\ \text{LPOP} - 0.0089\ \text{BLK} \\ & + .0023\ \text{URBAN} + 0.58\ \text{LNREC} + \text{error term}\end{aligned}$$

Where:

LRPAY = Logarithm of regular military compensation over a four year period, divided by full time equivalent earnings of civilian youth. Military and civilian earnings are discounted at 30 percent. Civilian earnings are aged with data on median weekly earnings of 16 to 19 year olds.

RUNEM = Change in the unemployment rate for all civilians.

LAVG = Logarithm of the average unemployment rate for all civilians in FY 1976-82.

VEAP = Dummy variable equal to zero in FY 1976T and one in FY's 1977-82. It measures the net effect of the change over from the GI Bill to VEAP.

LPOP = Logarithm of a district's 17 to 21 year old male population in thousands.

BLK = percent of a district's 17 to 21 year old male population that is black.

UPOP = Percent of a district's 17 to 21 year old male population that resides in a urban area.

LNREC = Logarithm of Navy's production recruiters.

In the results of their findings for mental groups I through III upper, they concluded that relative military pay, cyclical unemployment, total population, urban mix and recruiters increase enlistments, while black population and the loss of the GI Bill cause enlistments to decline. They determined that a one percent increase in relative military pay would cause an increase of Navy enlistments of 0.75 percent and that a one percent increase in the unemployment rate would increase enlistments by between 4.3 and 5.1 percent. Although they indicated that their results utilizing regional unemployment were inconsistant, it appeared that in general a rise in regional unemployment caused a rise in enlistments in the region.

They found that the loss of the GI Bill caused a decline in the supply of target candidates of 26 percent to the Navy. They additionally determined districts having greater population tended to have more recruiters resulting in their separate effects being difficult to measure. They did determine that a doubling of recruiters and population results in slightly more than a doubling of enlistments, and that a one percent rise in the urban population increased enlistments by one to two tenths of a percent. Overall, they concluded that the research approach using annual time series, cross-sectional data was fruitful and that additional research will enhance the usefulness of this model for forecasting and policy analysis.

# III. APPLICATION OF BOX-JENKINS

## A. ANALYSIS STEP ONE

The Box-Jenkins methodology was applied to a monthly time series of nonprior service high school graduate males signing contracts in the Albuquerque, New Mexico recruiting district during the period October 1978 to September 1983 (60 data points). The data was limited to those contract signers in mental groups I through III upper and represented net contracts signed, that is new contracts signed less Delayed Entry Program (DEP) attrites. Figure 3.1 is a time series plot of this data. This plot suggests strong seasonality in the number of high quality male enlistes with peak months appearing to be in late summer, predominately August, and in January. An "average" year was constructed by averaging the individual months over the five year period. Figure 3.2 is the time series plot of this average year. The average for each month is denoted by the letter "A". Also depicted in the graph is the average of the contracts signed in the first three years of the data series denoted by "1" and the average of the last two years denoted by "2". The average of all the years ,"A", tends to support the assumption of seasonality suggested in the time seris plot of the data set. However, in the plot of the last two years alone, the suggestion for seasonality is not as clear which would tend to indicate that some process change has taken place.

Of some interest is the apparent sudden increase in the mean number of contract signers over the approximate last third of the series. Further analysis indicates that for the time series as a whole the mean number of contracts

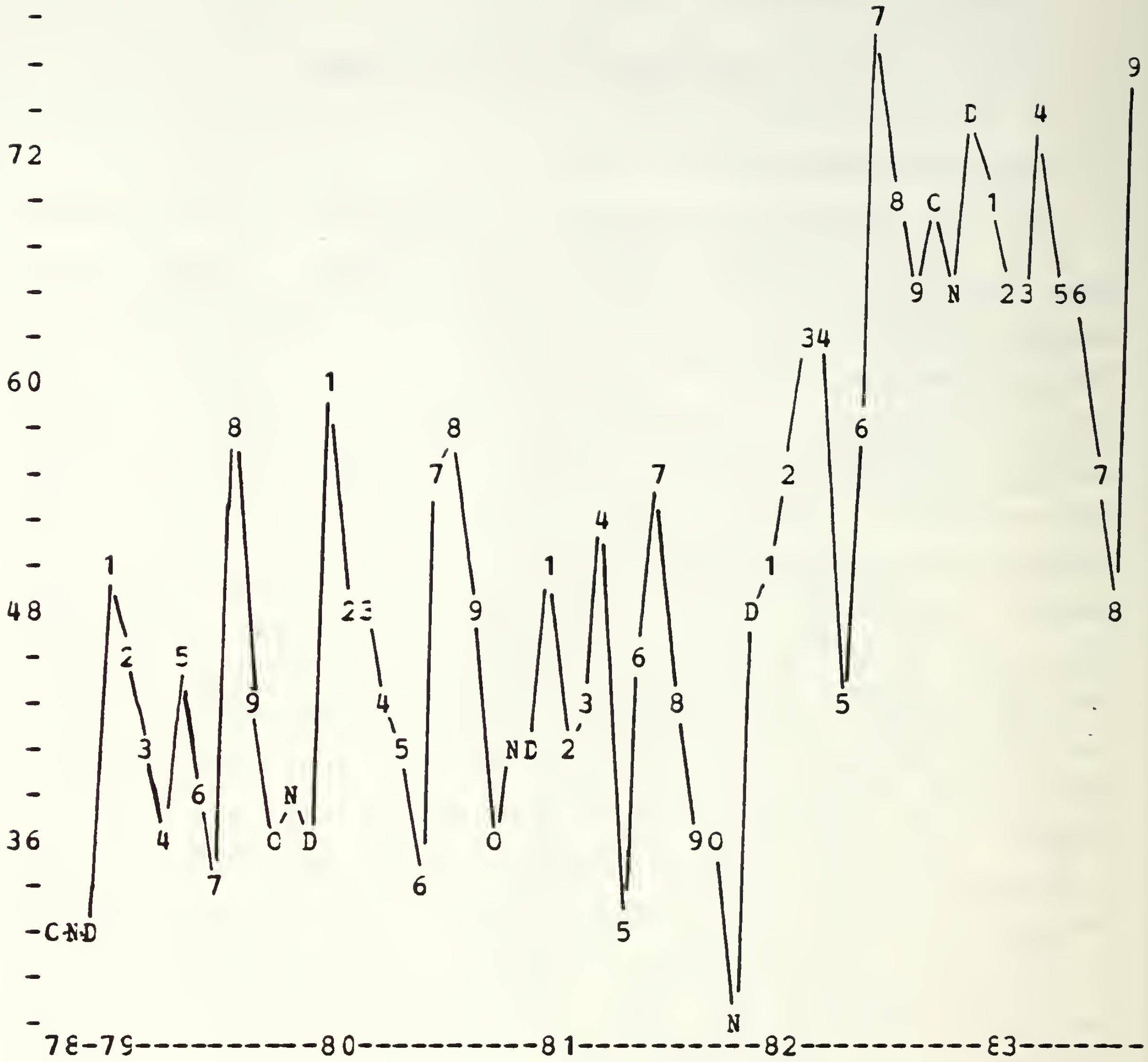

Figure 3.1 Monthly Contracts Signed.

signed per month was 49.07. For the approximate first two thirds of the series the mean was 42.83 and for the approximate last third the mean was 62.53. Because of this unusual pattern, two additional time series plots were constructed for this data. The first was a time series plot for the first forty one data points (October 1978 to February 1982), figure 3.3, and the second was for the last nineteen data points (March 1982 to September 1983), figure 3.4. Although no obvious trend is apparent in either data subset, both figures do provide some indication of seasonality.

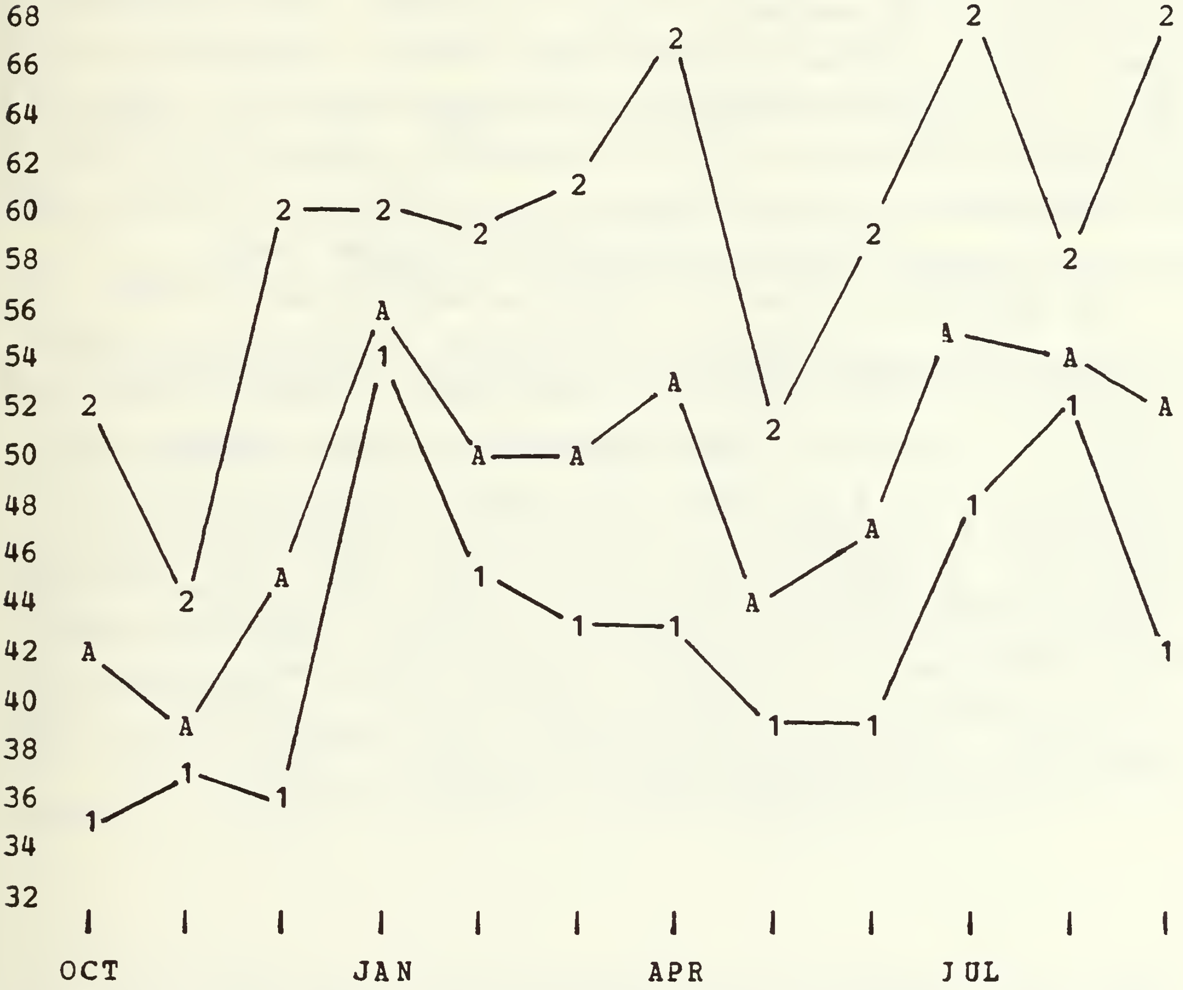

Figure 3.2 Average Recruiting Year.

The next step in developing the models for high quality recruitment was to plot the autocorrelations for the data sets. Figure 3.5 is the autocorrelation plot developed by the Minitab general purpose statistical computing system for the period October 1978 to September 1983. An examination of these autocorrelations indicate that non-stationary behavior in the process level (a trend) is evident in the the data. The evidence of such behavior is indicated by having autocorrelations which do not die out rapidly to zero. Although the autocorrelations for this data indicates a general trend in the data, the time series plots and the mean difference in the two data subsets tend to suggest not an overall trend, but a sudden and sustained overall increase in the number of contracts signed by the target cohort. This may be caused by some yet to be determined external influence. An evaluation of this sudden and sustained increase in contract signers will be addressed in Chapter Four.

Two separate courses of analysis were pursued. First, in the event that the cause of the sudden increase in the mean could not be identified and quantified, a model which was adequate to describe the data set as a whole was sought. Second, in the event that the cause could be identified, its' affect quantified and any future occurrance predicted, a single model which satisfactorily described the underlying data patterns of each subset around their mean was sought. If the cause of this sudden change could be determined or controlled, then the second model could possibly be used to more accurately forecast future contract signers.

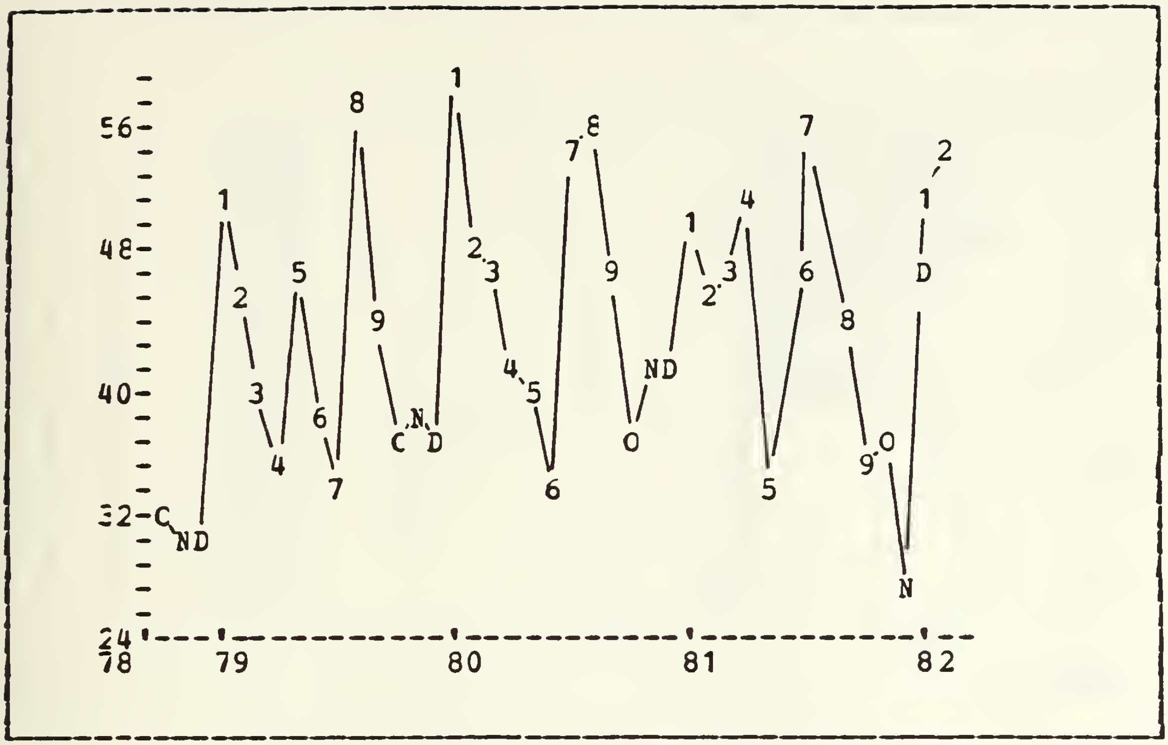

Figure 3.3 Monthly Contracts (Oct 78 - Feb 82).

## E. AUTOCORRELATIONS AND PARTIAL AUTOCORRELATIONS EXAMINED

### 1. October 1978 to September 1983

As evidenced by figure 3.5, there is a suggested trend for this data set due to the increase in the mean number of contracts signed. As the Box-Jenkins methodology requires stationary data to be effective, differencing[1] was used. This data set was differenced once and the resulting autocorrelations and partial autocorrelations, as represented in figures 3.6 and 3.7, were examined.

---

[1] Differencing is accomplished by subtracting the first value from the second, the second from the third, the third from the fourth, etc. Differencing is the most rapid method of removing a trend from a time series [Ref. 8]. Differencing may be performed once or more in order to remove the trend, however differencing once is usually adequate.

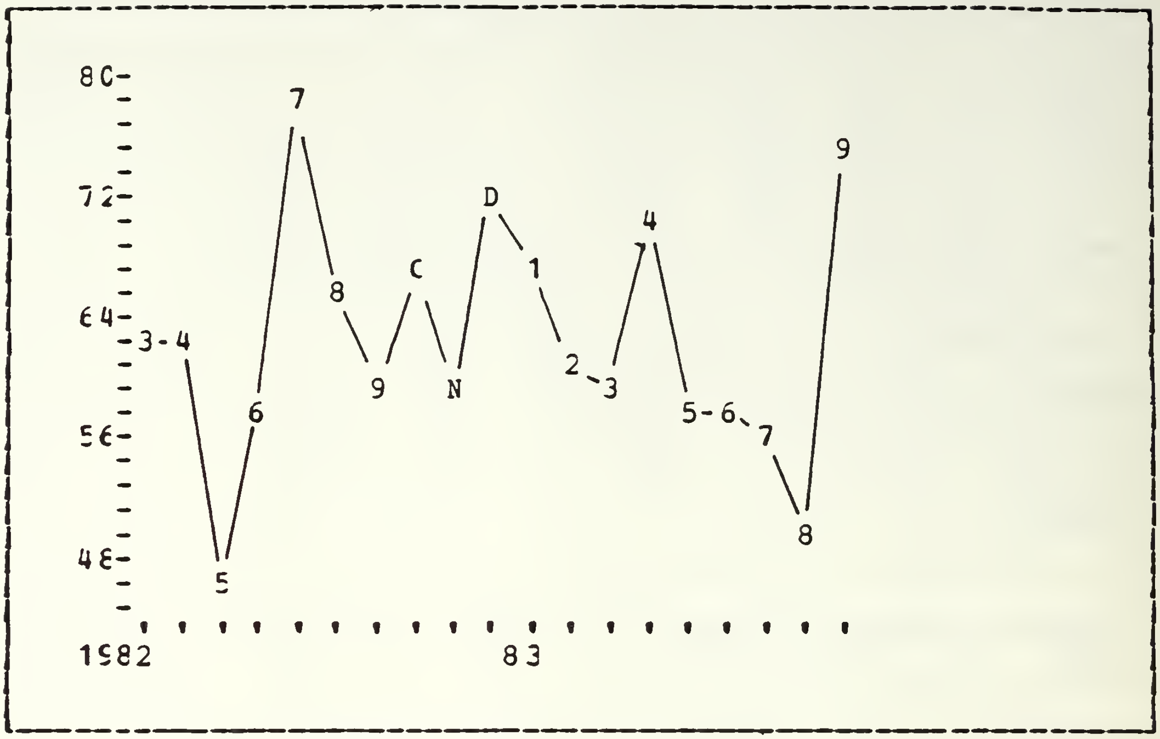

Figure 3.4 Monthly Contracts (Mar 1982 to Sep 1983).

Three statistically significant data points are observed in figure 3.6: the first, the twelfth and the thirteenth. Overall, this plot suggests that the trend has been removed and that only horizontal, stationary, data remains. The strong positive autocorrelation at the twelfth period supports the seasonality suggested by figures 3.1 and 3.2

### 2. October 1978 to February 1982 and March 1982 to September 1983

Figures 3.8 through 3.11 are the autocorrelations and partial autocorrelations for the periods October 1978 to February 1982 and March 1982 to September 1983 respectively. These plots suggest that both subsections of the data set are trendless, with a suggestion of seasonality evident only in the October 1978 to February 1982 data. Identification

```
                -0.6  -0.4  -0.2   0.0   0.2   0.4   0.6
                  '-----'-----'-----+-----'-----'-----'
 1    0.555                 '       XXXXXXXX'XXXXXXXXX
 2    0.404                 '       XXXXXXXX'XXX
 3    0.434                 '       XXXXXXXX'XXXX
 4    0.407                 '       XXXXXXXX'XXX
 5    0.468                 '       XXXXXXXX'XXXXX
 6    0.485                 '       XXXXXXXX'XXXXX
 7    0.343                 '       XXXXXXXX'XX
 8    0.272                 '       XXXXXXXX'X
 9    0.209                 '       XXXXXXX '
10    0.088                 '       XXX     '
11    0.227                 '       XXXXXXXX'
12    0.261                 '       XXXXXXXX'X
13    0.029                 '       XX      '
14   -0.003                 '       X       '
15   -0.032                 '      XX       '
16   -0.107                 '    XXXX       '
17    0.012                 '       X       '
18    0.073                 '       XXX     '
19   -0.027                 '      XX       '
20   -0.090                 '     XXX       '
                           -2SE            +2SE
```

Figure 3.5 AUTOCORRELATIONS.

```
                -0.6  -0.4  -0.2   0.0   0.2   0.4   0.6
                  '-----'-----'-----+-----'-----'-----'
 1   -0.296                X'XXXXXXXX       '
 2   -0.251                 'XXXXXXXX       '
 3    0.105                 '       XXXX    '
 4   -0.123                 '    XXXX       '
 5   -0.001                 '       X       '
 6    0.228                 '       XXXXXXXX'
 7   -0.073                 '     XXX       '
 8   -0.048                 '      XX       '
 9    0.026                 '       XX      '
10   -0.222                 'XXXXXXXX       '
11    0.068                 '       XXX     '
12    0.346                 '       XXXXXXXX'XX
13   -0.274                X'XXXXXXXX       '
14   -0.061                 '     XXX       '
15    0.190                 '       XXXXXXX '
                          -2SE            +2SE
```

Figure 3.6 AUTOCORRELATIONS OF DIFFERENCED DATA.

```
                  -0.6  -0.4  -0.2   0.0   0.2   0.4   0.6
                    '-----'-----'-----+-----'-----'-----'
      1   -0.296              'XXXXXXXX       '
      2   -0.371            XX'XXXXXXXX       '
      3   -0.136              '    XXXX       '
      4   -0.289              'XXXXXXXX       '
      5   -0.223              ' XXXXXXX       '
      6    0.040              '       XX      '
      7    0.009              '       X       '
      8    0.051              '       XX      '
      9    0.049              '       XX      '
     10   -0.219              '  XXXXXX       '
     11   -0.179              '   XXXXX       '
     12    0.178              '       XXXXX   '
     13   -0.119              '    XXXX       '
     14   -0.117              '    XXXX       '
     15    0.071              '       XXX     '
                            -2SE            +2SE
```

Figure 3.7 PARTIAL AUTOCORRELATIONS OF DIFFERENCED DATA.

```
                  -0.6  -0.4  -0.2   0.0   0.2   0.4   0.6
                    '-----'-----'-----+-----'-----'-----'
      1    0.129              '       XXXX    '
      2   -0.216              ' XXXXXXX       '
      3   -0.228              'XXXXXXXX       '
      4   -0.147              '   XXXXX       '
      5    0.093              '       XXX     '
      6    0.279              '       XXXXXXXX'
      7    0.162              '       XXXXX   '
      8   -0.016              '       X       '
      9   -0.269              'XXXXXXXX       '
     10   -0.162              '   XXXXX       '
     11    0.263              '       XXXXXXXX'
     12    0.309              '       XXXXXXXX'X
     13   -0.093              '     XXX       '
     14   -0.201              ' XXXXXXX       '
     15   -0.195              ' XXXXXXX       '
                            -2SE            +2SE
```

Figure 3.8 AUTOCORRELATIONS (OCT 78 - FEB 82).

and estimation of the seasonal nature of these two subsets is very difficult because of the brevity of the time series.

```
                  -0.6  -0.4  -0.2   0.0   0.2   0.4   0.6
                    !-----!-----!-----+-----!-----!-----!
      1    0.129              !       XXXX    !
      2   -0.236              !XXXXXXXX       !
      3   -0.176              !   XXXXX       !
      4   -0.159              !   XXXXX       !
      5    0.044              !       XX      !
      6    0.185              !       XXXXXX  !
      7    0.110              !       XXXX    !
      8    0.071              !       XXX     !
      9   -0.153              !   XXXXX       !
     10   -0.040              !      XX       !
     11    0.251              !       XXXXXXXX!
     12    0.170              !       XXXXX   !
     13   -0.208              ! XXXXXXX       !
     14   -0.128              !    XXXX       !
     15   -0.057              !      XX       !
                            -2SE            +2SE
```

Figure 3.9 PARTIAL AUTOCORRELATIONS (OCT 78 - FEB 82).

```
                  -0.6  -0.4  -0.2   0.0   0.2   0.4   0.6
                    !-----!-----!-----+-----!-----!-----!
      1   -0.045              !      XX       !
      2   -0.292              !XXXXXXXX       !
      3    0.012              !       X       !
      4   -0.052              !      XX       !
      5    0.127              !       XXXX    !
      6    0.056              !       XX      !
      7   -0.335             X!XXXXXXXX       !
      8   -0.132              !    XXXX       !
      9    0.222              !       XXXXXXXX!
     10   -0.096              !     XXX       !
     11   -0.067              !     XXX       !
     12   -0.095              !     XXX       !
     13   -0.081              !     XXX       !
     14    0.300              !       XXXXXXXX!X
     15    0.153              !       XXXXX   !
                            -2SE            +2SE
```

Figure 3.10 AUTOCORRELATIONS (MAR 82 - SEP 83).

```
                  -0.6  -0.4  -0.2   0.0   0.2   0.4   0.6
                    :-----:-----:-----+-----:-----:-----:
      1   -0.045              :      XX       :
      2   -0.295             X:XXXXXXXX       :
      3   -0.020              :      XX       :
      4   -0.153              :   XXXXX       :
      5    0.126              :       XXXX    :
      6    0.009              :       X       :
      7   -0.286              :XXXXXXXX       :
      8   -0.186              :  XXXXXX       :
      9    0.048              :       XX      :
     10   -0.213              : XXXXXXX       :
     11   -0.102              :    XXXX       :
     12   -0.227              :XXXXXXXX       :
     13   -0.148              :   XXXXX       :
     14    0.059              :       XX      :
     15    0.030              :       XX      :
                            -2SE             +2SE
```

Figure 3.11 PARTIAL AUTOCORRELATIONS (MAR 82 - SEP 83).

## C. MODEL DEVELOPMENT

In comparing the autocorrelations and partial autocorrelations to the various ARMA models in figures A.5 through A.13, a moving average model is suggested for the data set for October 1978 to September 1983 as well as for each subset of the data. However, which particular MA model would best describe the underlying data pattern in each case is unclear.

### 1. October 1978 to September 1983

Taking into consideration the apparent seasonality of the data set, the apparent trend in the data and the uncertainty as to which specific MA model would be most appropriate , two models were developed for evaluation based on a visual inspection of the autocorrelations and partial autocorrelations.

a. First Order, Seasonal, Moving Average Model with the form:

$$Y_T - Y_{T-1} = \triangle Y_T = (1-\theta_1 B)(1-\theta_{12} B^{12})\, e_T \qquad \text{(eqn 3.1)}$$

b. Second Order, Seasonal, Moving Average Model with the form:

$$Y_T - Y_{T-1} = \triangle Y_T = (1-\theta_1 B-\theta_2 B^2)(1-\theta_{12} B^{12})\, e_T \qquad \text{(eqn 3.2)}$$

Where e is the error term.

2. October 1978 to February 1982

In developing the models to be tested for this data subset, the absence of an apparent trend, the suggested seasonality, and the uncertainty as to which particular moving average model would best describe the underlying data patterns were taken into consideration. Two models were selected for evaluation based on a visual inspection of the autocorrelations and partial autocorrelations.

a. First Order, Seasonal, Moving Average Model with the form:

$$Y_T = (1-\theta_1 B)(1-\theta_{12} B^{12})\, e_T \qquad \text{(eqn 3.3)}$$

b. Second Order, Seasonal, Moving Average Model with the form:

$$Y_T = (1-\theta_1 B-\theta_2 B^2)(1-\theta_{12}B^{12})e_T \qquad \text{(eqn 3.4)}$$

Where $e$ is the error term.

### 3. March 1982 to September 1983

In developing the models to be tested for this data subset, the absence of an apparent trend, insufficient length in the time series to exhibit seasonality, and the uncertainty as to which particular moving average model would best describe the data patterns were taken into consideration. Two models were selected for evaluation based on a visual inspection of the autocorrelations and partial autocorrelations.

a. First Order Moving Average Model with the form:

$$Y_T = (1-\theta_1 B)e_T \qquad \text{(eqn 3.5)}$$

b. Second Order Moving Average Model with the form:

$$Y_T = (1-\theta_1 B-\theta_2 B^2)e_T \qquad \text{(eqn 3.6)}$$

Where $e$ is the error term.

## D. MODEL EVALUATION

The models developed were evaluated utilizing the Minitab general purpose statistical computing system command

"ARIMA" (Autoregressive Integrated Moving Average).[2] In order for a model to be considered adequate the residuals (errors) of the estimates generated by the model would be required to be random (uncorrelated) with a mean of zero. If each of the models developed for each specific data set satisfied this requirement, the sum of squared errors and the T-ratios for each model would be examined to determine the most appropriate model. The results of this evaluation are contained in Table I.

## E. RESULTS OF THE MODEL EVALUATION

### 1. October 1978 to September 1983

As evidenced by table I, both models considered satisfied the requirement of random residuals. There exists little difference between the two models to suggest which is the more appropriate, although confidence in the second model is reduced by the low T-ratio for the MA(2) operator. In this case the principle of parsimony[3] was invoked and the selected model was the MA(1) with the form:

$$Y_T = (1-.644B)(1+.448B^{12})e_T \qquad \text{(eqn 3.7)}$$

$$(.101) \qquad (.162) \qquad \text{std. error}$$

---

[2] The concepts and notations used by this command follow the ones developed by Box and Jenkins. The values of $\emptyset$ and $\Theta$ are determined utilizing a nonlinear least squares algorithm developed by Marquart. The ARIMA command fits non-seasonal and seasonal models to a time series with input consisting of a stored time series and information as to the degree of the AR, MA or ARMA model to be fitted [Ref. 9].

[3] The principle of parsimony cautions to attempt to use the smallest possible number of parameters which represent the model adequately [Ref. 10].

### 2. October 1978 to February 1982

The two models selected for this data subset were run with results displayed in Table I. The residuals for both models met the randomness requirement, however the low T-ratios for the non-seasonal coefficients in both models was less than encouraging. As a result of these low T-ratios, another model, SMA(1), was attempted. This model has the form:

$$Y_T = \theta_0 + (1 - \Theta_{12} B^{12}) e_T \qquad \text{(eqn 3.8)}$$

An examination of Table I for this data set indicates little to distinguish one model from another in terms of more adequately describing the data patterns. Again the rule of parsimony was used. The model selected was the SMA(1) model with the form:

$$Y = 42.46 + (1 + .778B^{12}) e_T \qquad \text{(eqn 3.9)}$$

$$(1.78) \qquad (.203) \qquad \text{std. error}$$

### 3. March 1982 to September 1983

Here, again, each model selected for evaluation satisfied the requirement for random residuals. The significant difference between these two models is in the residual sum of squared errors, where the MA(2) model is clearly superior to the MA(1) model. Also encouraging is the significant T-ratio exhibited by the MA(2) coefficient in the second model. The model selected for forecasting purposes was:

$$Y = 62.95 + (1-.250B-.745B^2)e_T \qquad \text{(eqn 3.10)}$$

$$(0.23) \quad (.208) \; (.208) \text{ std. error}$$

## F. FORECASTING WITH THE SELECTED MODELS

Table II and figures 3.12 through 3.15 represent the results of the forecasts of the selected models. The actual values for the net number of target cohort contracts signed and the forecasted values are displayed within each table section. The 95 percent limits displayed indicate that one should be certain that the actual value will fall between these two values 95 percent of the time. In figures 3.12 through 3.15, the forecast results are displayed graphically. The actual net contracts signed are dipicted by the letter "A", the forecasted values by the letter "F" and the upper and lower 95 percent confidence limits by the letters "U" and "L" respectively.

Table II is divided into four sections. The first section, corresponding to figure 3.12, is a forecast for six periods ahead for the period October 1983 to March 1984 based on the October 1978 to September 1983 time series utilizing the seasonal MA(1)D model previously selected for this time series. With the exception of the March 1984 forecast, all actual values fall within the 95 percent confidence limits, however, these confidence limits are too wide to be of much practical value. As evidenced by figure 3.12, the model does generally capture the pattern of enlistments for the forecasted period, although the degree of the decrease for March 1984 is not well represented. The variation in the forecasting errors, ranging from a low of +5.0 percent to a high of +67.4 percent are not particularly encouraging.

In the second section, corresponding to figure 3.13, the forecasts are conducted on a month to month basis utilizing the sequential[4] forecasting method. For example, the initial forecasts for this data set were conducted utilizing 60 data points. When the 61 st data point became available, the parameters of the same model specification were reestimated using 61 data points and a forecast for period 62 was conducted. Forecasts were conducted in this manner for the period October 1983 to March 1984. As evidenced by section Two of the table, forecasting with this method produces superior results to forecasting multiple periods ahead. For the most part, forecasted values well represent the actual values, although here again the model fails to adequately represent the sudden decrease for March 1984.

In sections three and four of Table II, corresponding to figures 3.14 and 3.15 respectfully, the forecasts of the MA(2) model developed for the March 1982 to September 1983 time series are examined. Section three, as in section one of the table, is a forecast for six periods ahead. The obvious problem of attempting to forecast future periods with a non-differenced MA model is the models tendency to forecast the mean of the time series after only a few periods, precluding any meaningful evaluation of these forecasts. Observing the first two forecasts for the period October 1983 to March 1984, the results are not very encouraging. The errors for these two periods are much too large to be of any practical application.

In section four the forecasts were conducted with the sequential forecasting method utilizing the March 1982 to September 1983 time series. With only one forecasted value falling within ten percent of the actual value, and with the forecasts being conducted only one period ahead, the model would appear to have extremely limited usefulness.

---

[4] As soon as the value of the next data point becomes available, all forecasts for future periods are updated utilizing reestimated parameter values of the ARMA model, as opposed to the adaptive method in which the ARMA model parameters remain unchanged.

Of the two models developed, the Seasonal MA(1)D model developed for the October 1978 to September 1983 time series would seem to be the most useful in forecasting future net values of high quality recruits. However, as evidenced by Table II and Figures 3.12 and 3.13, sudden major swings in the values of contracts signed are not adequately predicted by this model. In Chapter Four a causal model utilizing regression analysis will be examined for applicability, and to determine if sudden shifts in the dependent variable will be adequately described by a causal model.

# TABLE I

## MODEL EVALUATION RESULTS

### October 1978 to September 1983

| | MA(1)D | MA(2)D |
|---|---|---|
| Residuals: | Random | RANDOM |
| Mean: | +0.80 | +1.03 |
| Std Dev: | 8.89 | 8.66 |
| Significance Level for Mean: | 2.32 | 2.26 |
| Residual Sum of Squares: | 4619.61 | 4416.89 |
| T-Ratios: | | |
| MA(1) | +6.39 | +3.46 |
| MA(2) | NA | +1.72 |
| SMA(1) | -2.76 | -3.01 |

### October 1978 to February 1982

| | MA(1) | MA(2) | SMA(1) |
|---|---|---|---|
| Residuals: | Random | Random | Random |
| Mean: | +0.76 | +0.73 | +0.75 |
| Std Dev: | 6.27 | 6.35 | 6.37 |
| Significance Level for Mean: | 1.96 | 1.98 | 2.00 |
| Residual Sum of Squares: | 1594.85 | 1634.77 | 1646.43 |
| T-Ratios: | | | |
| MA(1) | -1.05 | -0.91 | NA |
| MA(2) | NA | -0.03 | NA |
| SMA(1) | -3.52 | -3.73 | -3.83 |
| Constant: | 42.37 | 42.43 | 42.46 |

Actual mean for times series: 42.83

### March 1982 to September 1983

| | MA(1) | MA(2) |
|---|---|---|
| Residuals: | Random | Random |
| Mean: | -0.02 | +0.42 |
| Std Dev: | 8.48 | 7.13 |
| Significance Level for Mean: | 3.89 | 3.27 |
| Residual Sum of Squares: | 1294.39 | 918.04 |
| T-Ratios: | | |
| MA(1) | +0.54 | +1.20 |
| MA(2) | NA | +3.59 |
| Constant: | 62.47 | 62.95 |

Actual mean for the time series: 62.53

# TABLE II

## FORECAST RESULTS

### OCTOBER 1978 TO SEPTEMBER 1983 DATA SET FORECASTS

FORECASTING SIX PERIODS AHEAD

| | | 95 PERCENT LIMITS | | | |
|---|---|---|---|---|---|
| MONTH | FORECAST | LOWER | UPPER | ACTUAL | % ERROR |
| OCT 83 | 65.7 | 48.1 | 83.4 | 53 | +24.0 |
| NOV 83 | 64.4 | 45.6 | 83.1 | 52 | +23.8 |
| DEC 83 | 65.8 | 46.0 | 85.6 | 59 | +11.5 |
| JAN 84 | 63.4 | 42.7 | 84.1 | 59 | +07.5 |
| FEB 84 | 58.8 | 37.2 | 80.5 | 56 | +05.0 |
| MAR 84 | 56.9 | 34.3 | 79.4 | 34 | +67.4 |

SEQUENTIAL FORECASTING METHOD

| | | 95 PERCENT LIMITS | | | |
|---|---|---|---|---|---|
| MONTH | FORECAST | LOWER | UPPER | ACTUAL | % ERROR |
| OCT 83 | 65.7 | 48.1 | 83.4 | 53 | +24.0 |
| NOV 83 | 59.8 | 41.9 | 77.6 | 52 | +15.0 |
| DEC 83 | 58.5 | 40.8 | 76.3 | 59 | -00.8 |
| JAN 84 | 56.6 | 38.9 | 74.2 | 59 | -04.1 |
| FEB 84 | 53.6 | 36.1 | 71.1 | 56 | -04.3 |
| MAR 84 | 53.0 | 35.6 | 70.4 | 34 | +55.9 |

### MARCH 1982 TO SEPTEMBER 1983 DATA SET FORECASTS

FORECASTING SIX PERIODS AHEAD

| | | 95 PERCENT LIMITS | | | |
|---|---|---|---|---|---|
| MONTH | FORECAST | LOWER | UPPER | ACTUAL | % ERROR |
| OCT 83 | 69.2 | 54.3 | 84.0 | 53 | +30.6 |
| NOV 83 | 58.8 | 43.5 | 74.1 | 52 | +13.1 |
| DEC 83 | 63.0 | 44.1 | 81.8 | 59 | +06.8 |
| JAN 84 | 63.0 | 44.1 | 81.8 | 59 | +06.8 |
| FEB 84 | 63.0 | 44.1 | 81.8 | 56 | +12.5 |
| MAR 84 | 63.0 | 44.1 | 81.8 | 34 | +85.3 |

SEQUENTIAL FORECASTING METHOD

| | | 95 PERCENT LIMITS | | | |
|---|---|---|---|---|---|
| MONTH | FORECAST | LOWER | UPPER | ACTUAL | % ERROR |
| OCT 83 | 69.2 | 54.3 | 84.0 | 53 | +30.6 |
| NOV 83 | 61.3 | 44.2 | 78.5 | 52 | +17.9 |
| DEC 83 | 67.5 | 50.5 | 84.5 | 59 | +14.4 |
| JAN 84 | 63.1 | 46.2 | 79.9 | 59 | +06.9 |
| FEB 84 | 62.6 | 46.1 | 79.1 | 56 | +11.8 |
| MAR 84 | 61.5 | 45.2 | 77.8 | 34 | +80.8 |

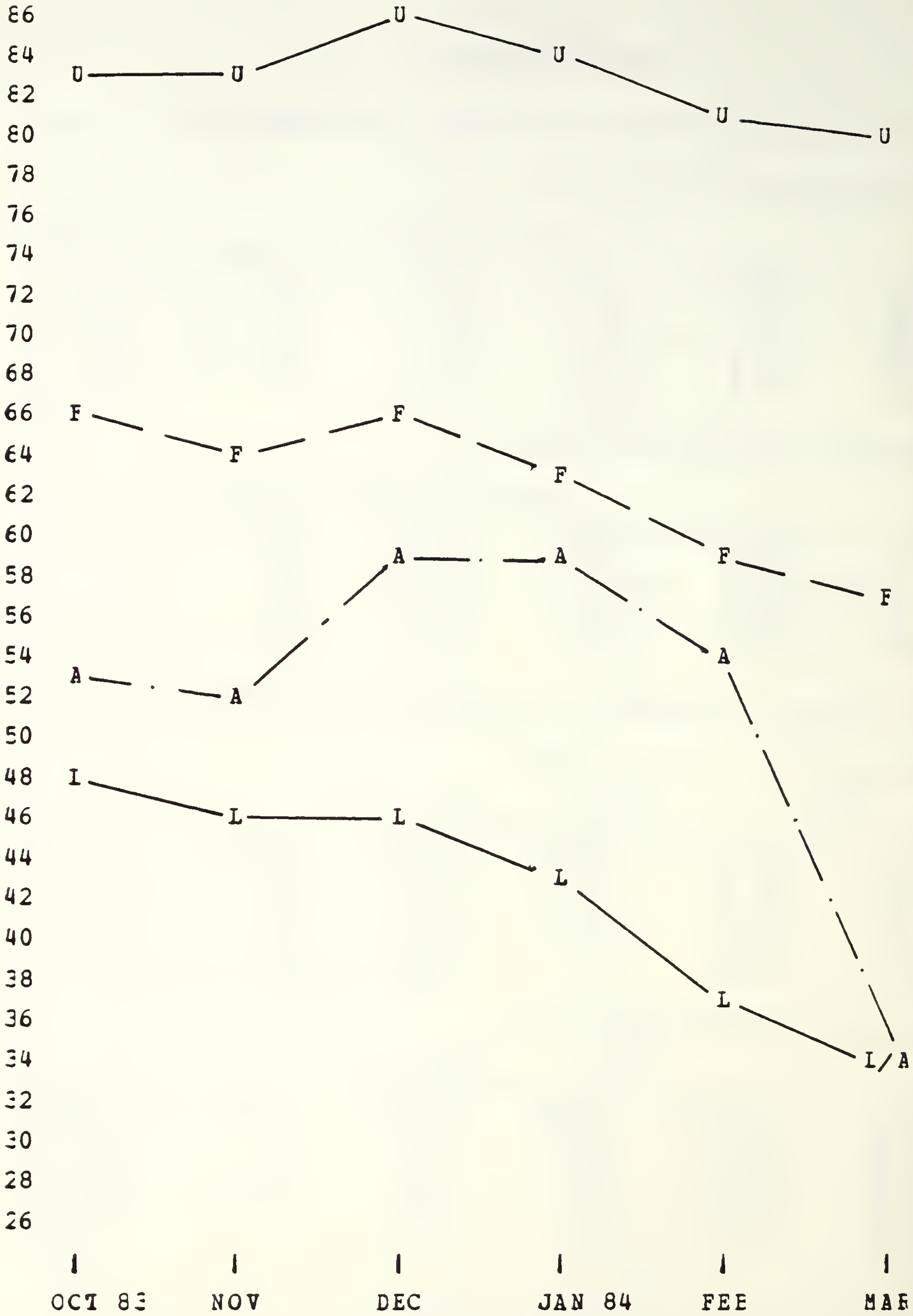

Figure 3.12 MA(1) SIX MONTH FORECAST.

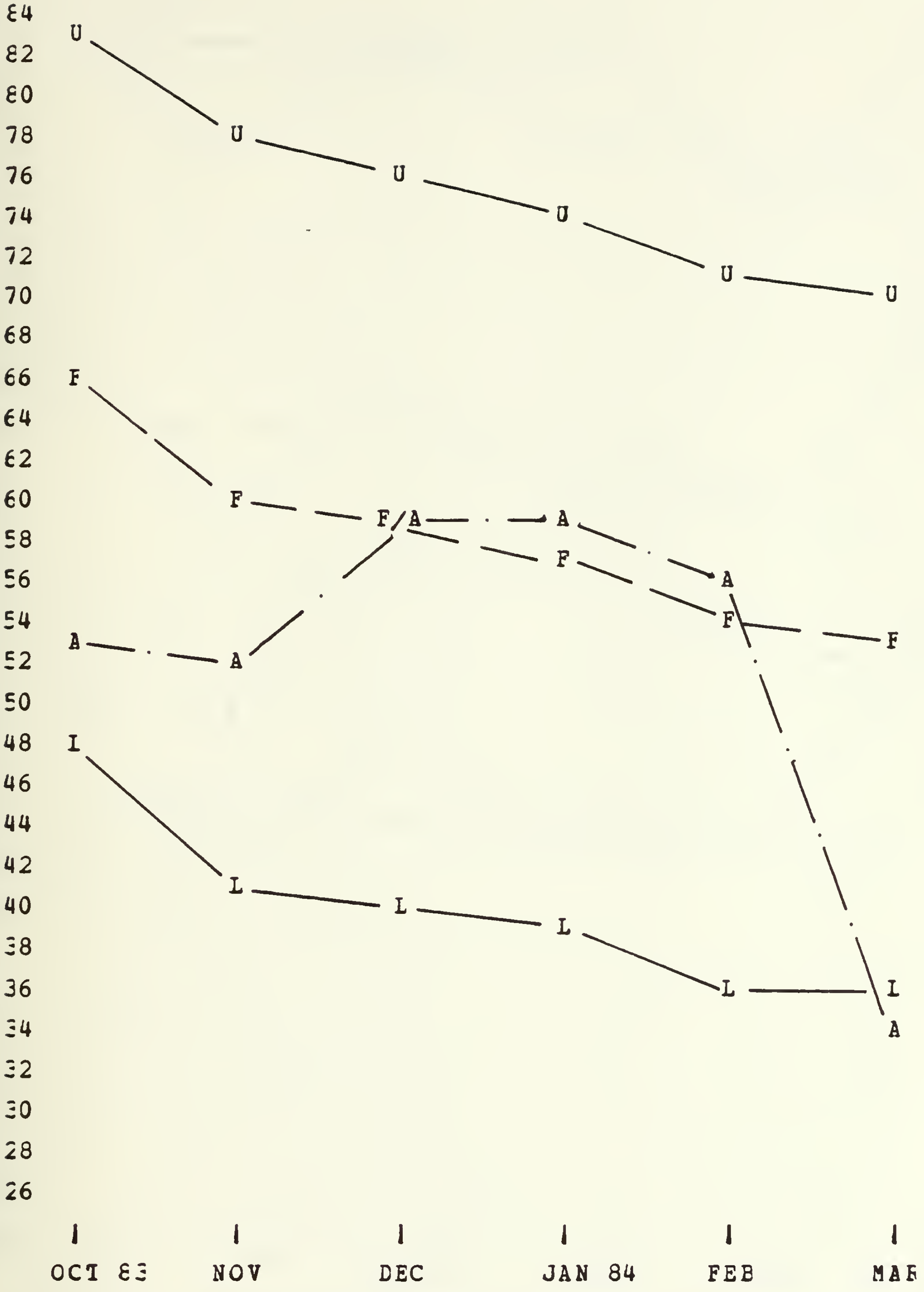

Figure 3.13 MA(1) SEQUENTIAL FORECASTS.

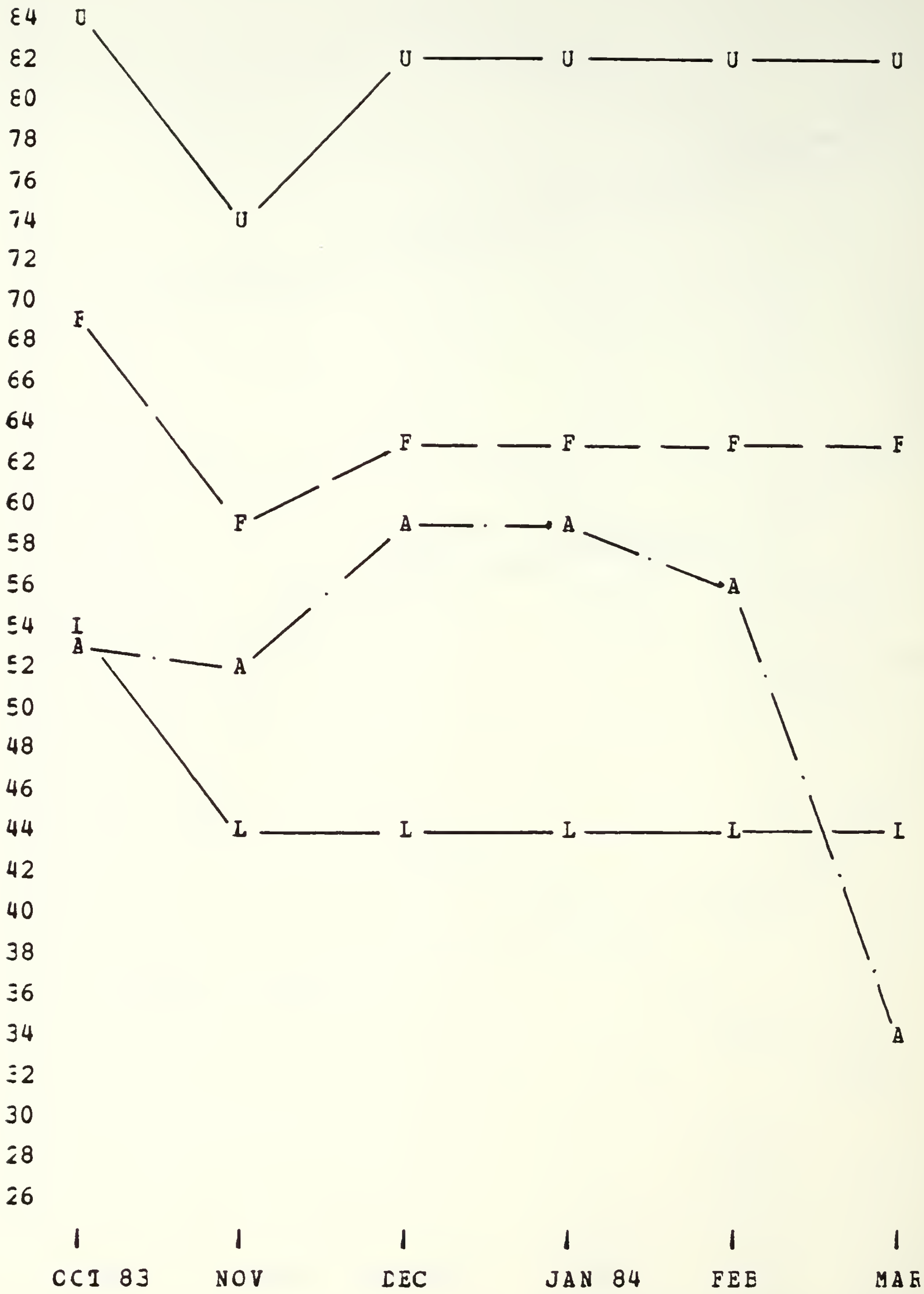

Figure 3.14 MA(2) SIX MONTH FORECAST.

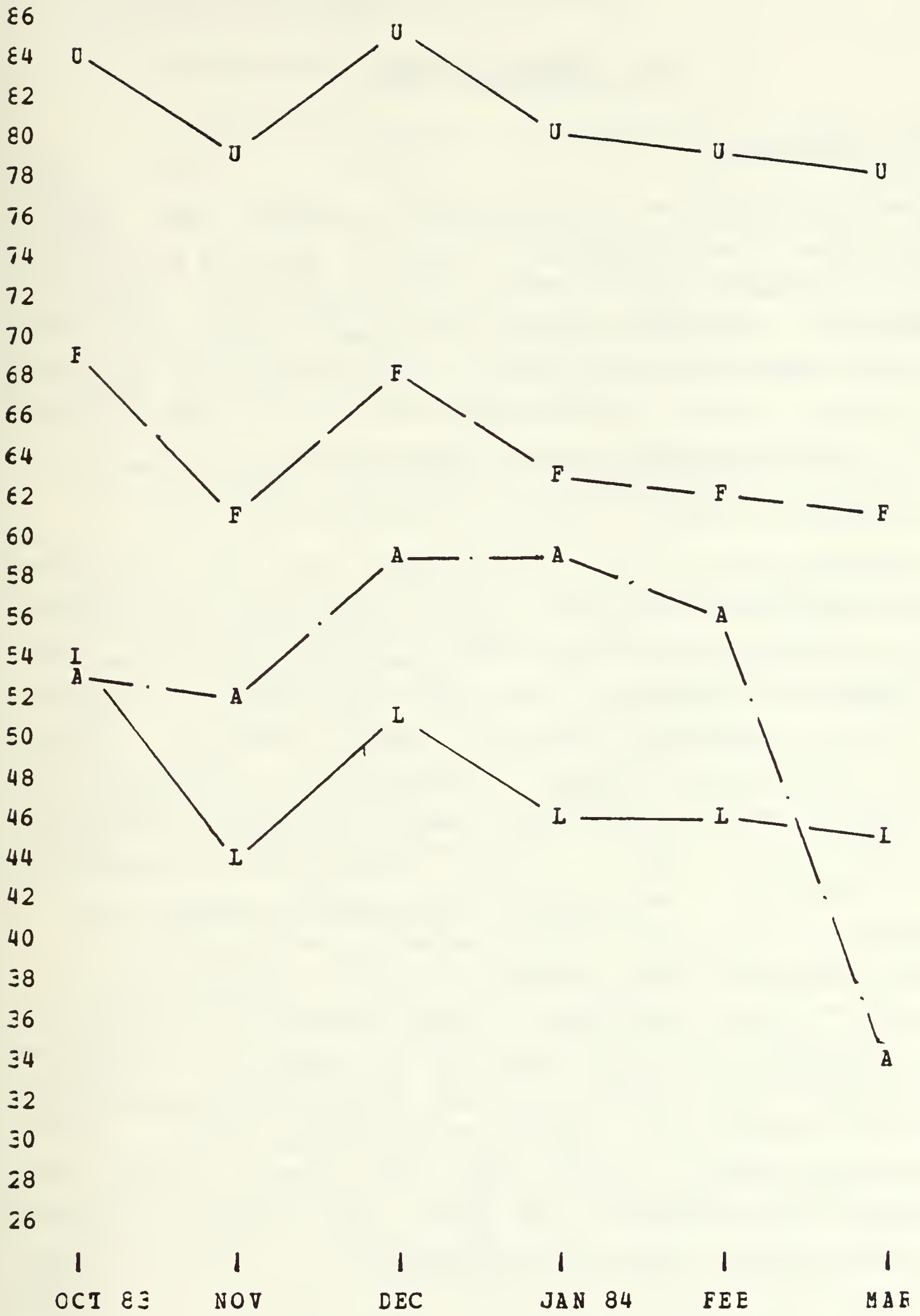

Figure 3.15 MA(2) SEQUENTIAL FORECASTS.

# IV. THE REGRESSION MODEL

## A. BASIC ASSUMPTIONS

It was assumed that the forecasts generated with the ARIMA model presented in Chapter 3 could be improved upon by developing a model which took into consideration causal relationships. The factors assumed to most actively influence the net number of high quality nonprior service males opting to join the Navy was conjectured to be: number of production recruiters, some measure of unemployment, size of the work force, military/civilian pay ratio and recruiting goals.

The utilization of the regression model requires that four basic assumptions be made. First, that the dependent variable, net contracts signed, is linearly related to each of the independent variables. If the relationships are not linear, then regression analysis cannot accurately be applied to the problem. Second, the variance of the residuals (errors) of the regression equation remains constant over the time series. Third, that the residuals are independent of one another, that is any given residual should not be a function of the error terms preceeding or following it in the time series. The existence of such a relationship, called serial (auto) correlation, implies that either an important independent variable has been omitted or the wrong functional form has been used in the regression equation. Generally for a data set of the size used in this study, a Durbin-Watson statistic value between 1.5 and 2.5 implies a lack of serial correlation. The final basic assumption is that the residuals are normally distributed.

## E. VARIABLES CONSIDERED FOR INCLUSION

### 1. Net Contracts Signed: CNTRCTS

As previously defined, the dependent variable is the total number of contracts signed per month by nonprior service high school graduate males in mental groups I through III upper within the Albuquerque, New Mexico Recruiting District less the number of Delayed Entry Program (DEP) attrites of the same cohort during the same month. This data was obtained from Navy Recruiting Command for the period October 1978 to September 1983.

### 2. The Number of Production Recruiters: RCTRS

The values for this variable are the number of Navy Recruiters who were actually on duty in Navy Recruiting District Albuquerque during the period of the time series. They represent actual canvassers and exclude staff personnel. This data was obtained from Navy Recruiting Command. It would seem to be logical to expect an increase in the number of production recruiters to result in an increase in the number of contracts signed, subject to effects of marginal productivity.

### 3. Numbers of Unemployed: UNEMPLD

The values for this variable represent the numbers of people determined to be unemployed by the U. S. Department of Labor. The values of this variable were divided by 10,000 so that the data could be manipulated more easily. These values were divided by 10,000 so that the data could be manipulated more easily. These values were built up from a county level and represent the seasonally adjusted number of unemployed within the target recruiting district as a whole. No breakdown by sex or age group was available. This data was obtained from Navy Recruiting

Command. It was assumed that an increase or decrease in the numbers of unemployed would result in a corresponding increase or decrease in the number of contracts signed.

4. Numbers in the Work Force: WKFRCE

The values for this variable represent the numbers in the work force, employed and unemployed, as determined by the U.S. Department of Labor. The values of this variable were built up from a county level and represent the seasonally adjusted work force in the target recruiting district in total. This data was obtained from Navy Recruiting Command. As the values for this variable increased or decreased, it was expected that the numbers of contracts signed would increase or decrease correspondingly.

5. Military/Civilian Pay Ratio: PAYRATIO

The merits of any constructed military / civilian pay ratio could be argued indefinitely with no concrete results as to a most meaningful measure. For the purposes of this study, the military component of the ratio was calculated as monthly base pay for an E-1 with more than three months service. The civilian component utilized was average weekly earnings of production workers in the state of New Mexico multiplied by four. The average weekly earnings figure was obtained from "Employment and Earnings" published by the U.S. Department of Labor; Bureau of Labor Statistics. Intuitively, an increase in the military/ civilian pay ratio would result in an increase in contracts signed.

6. Percent Unemployed: PERCUNE

The values of this variable are UNEMPLD/WKFRCE. This variable represents the percentage unemployed in the target recruiting district. This variable was included in the study to determine if the percentage of unemployed within the work force more accurately predicted the number of contracts signed than the ordinal value of unemployed.

### 7. Change in Unemployment: DELTAUN

The Values for this variable represent the month to month changes (+/-) of the variable PERCUNE for the target recruiting district. This variable was included in the study to determine if changes in the unemployment rate could signal corresponding changes in the number of contracts signed.

### 8. Unemployment Ratio: UNEMRAT

The values of this variable represent a ratio of the change in unemployment from month to month within the target recruiting district as expressed by the following formula:

$$\text{UNEMRAT} = \frac{\text{UNEMPLD in month T} - \text{UNEMPLD in month T-1}}{\text{UNEMPLD in month T-1}}$$

It was hoped that this variable could capture the effects of both the percentage unemployed and the change in unemployment on a monthly basis.

### 9. Goals - Quotas

Unfortunately, there was insufficient data on goals for the target cohort to examine goals for inclusion in the regression equation. Intuitively, goaling would seem to play a key role in determining the number of contracts signed. A recruiting district which had achieved target quotas for the month would be tempted to delay additional accessions until the following month to help insure the attainment of goals on a continuing basis. Additionally, goals would seem to mask the supply function of recruiting making the study of the supply problem much more difficult.[5] It is the hypothesis of this author that a detailed study of the effects of goals on enlistment contracts signed would indicate a very high positive relationship bewteen these two variables. This is an area which demands increased attention and study.

## C. THE REGRESSION MODEL DEVELOPED

In determining the final choice for the explanatory variables, it was necessary to determine the lag or lead effect, if any, that was exerted on the dependent variable by each independent variable. For example, an increase in the number of production recruiters may not affect the number of contracts signed for several months, assuming that there is a learning curve associated with the position. Similarly, an increase in the unemployment rate may not affect enlistments for several months. All of the independent variables previously described were given a lag and lead of from one to six months and simple regressions were conducted to determine which increment of lag or lead best explained the variation in the number of contracts signed. A variable was allowed to enter the equation only once. That is if, for example, PERCUNE evidenced a significant influence on CNTRCTS lagged one month and lagged two months, only the lag with the most significant coefficient of determination, R-squared, was included in the regression equation.[6]

---

[5] Siegel and Borack [Ref. 2] provide an excellent dicussion of the interaction between goals and the recruiting effort.

[6] The decision to utilize a single lag or lead for each variable was made prior to conducting the initial regression. However, during the the analysis, all variable lags and leads with a T-ratio greater than 2.00 for a simple regression were fitted into a multiple regression. The coefficient of determination of this multiple regression was not significantly different from the coefficient of determination for the multiple regression utilizing a single best fit lag or lead for each variable.

A multiple regression model utilizing the lag or lead of each variable with the highest coefficient of determination was constructed, and a regression conducted on the dependent variable net contracts signed with results as follows:

$$\begin{aligned} Y = & -42.6 + .405\,\text{RCTRS1} + 6.0\,\text{UNEMPLD1} - 1.0\,\text{WKFRCE1} \\ & + 256.0\,\text{PAYRATO4} - 241.0\,\text{PERCUNE2} + 28.2\,\text{DELTAUN} \\ & + 16.8\,\text{UNEMRAT2} + a \qquad \text{(eqn 4.1)} \end{aligned}$$

where:

RCTRS1 = number of production recruiters lagged 1 month
UNEMPLD1 = unemployment lagged 1 month
WKFRCE1 = numbers in the work force lagged 1 month
PAYRATO4 = military / civilian payratio lagged 4 months
PERCUNE2 = percent unemployed lagged 2 months
DELTAUN = change in unemployment with no lag
UNEMRAT2 = unemployment ratio lagged 2 months
a = residual

```
                                    ST. DEV.      T-RATIO=
COLUMN       COEFFICIENT            OF COEF.      COEF/S.D.
CONSTANT          -42.6               158.9          -0.27
RCTRS1           0.4051              0.2668           1.52
UNEMPLD1           5.97               17.81           0.33
WKFRCE1           -0.51               1.187          -0.43
PAYRATO4         256.17               96.18           2.66
PERCUNE2           -241                2498          -0.10
DELTAUN           28.23               10.26           2.75
UNEMRAT2          16.81               11.52           1.46

THE ST. DEV. OF Y ABOUT THE REGRESSION LINE IS
S= 8.030

R-SQUARED = 62.2 PERCENT
R-SQUARED = 56.7 PERCENT, ADJUSTED FOR D.F.
```

```
ANALYSIS OF VARIANCE

 DUE TO      DF            SS             MS=SS/DF
REGRESSION    7        5097.30             728.19
RESIDUAL     48        3094.84              64.48
TOTAL        55        8192.14
```

Those variables with negative T-ratios were excluded from consideration in the final regression model as having counter intuitive results. The regression was conducted a second time utilizing the variables: RCTRS1, UNEMPLD1, PAYRATO4, DELTAUN, and UNEMRAT2. The results of this second regression were examined and those variables having a T-ratio[7] less than 2.00 were eliminated from consideration in the final model. A third multiple regression was then conducted with the following results:

Y=-61.8+4.UNEMPLD1+193.PAYRATO4+19.8DELTAUN+a (eqn 4.2)

where:

UNEMPLD1 = unemployment lagged 1 month
PAYRATO4 = military/civilian payratio lagged 4 months
DELTAUN = change in unemployment with no lag
a = residual

```
                                      ST. DEV.     T-RATIO =
       COLUMN      COEFFICIENT        OF COEF.     COEF/S.D.
       CONSTANT         -61.84           35.11         -1.76
       UNEMPLD1          3.670           0.545          6.61
       PAYRATO4         193.26           90.35          2.14
       DELTAUN          19.785           9.410          2.10

THE ST. DEV. OF Y ABOUT REGRESSION LINE IS
S = 8.112
```

---

[7] A high T-ratio indicates that the independent variable is important in explaining the value of Y. The higher the T-ratio, the more unlikely that the b coefficient is a random variation from zero.

```
R-SQUARED = 58.2 PERCENT
R-SQUARED = 55.8 PERCENT, ADJUSTED FOR D.F.

ANALYSIS OF VARIANCE

 DUE TO      DF          SS       MS=SS/DF
REGRESSION    3     4770.27        1590.09
RESIDUAL     52     3421.88          65.81
TOTAL        55     8192.15
```

The signs of the coefficients of the explanatory variables are what one would expect intuitively. As unemployment increases, so does the number of contracts signed. An increase in the military/civilian pay ratio will cause an increase in the number of contracts signed, and as the percentage unemployment changes, the numbers of contracts signed change accordingly.

One of the more surprising results of the regression was the exclusion of the variable RCTRS, representing the number of production recruiters. When forced into the regression equation, the coefficient for this variable was never significantly differed from zero. Experience and intuition would indicate that recruiters play an important role in the numbers of high quality nonprior service males enlisting in the Navy.

There may be several explanations for the results of the regression in regards to recruiters. In examining the time series plots for CNTRCTS and RCTRS contained in Appendix B, it is evident that over the approximate last half of the period the numbers of contracts signed is increasing as the number of production recruiters is decreasing. It is possible that as the Navy gains more experience in the selection of recruiters, better recruiters are placed with the recruiting districts, resulting in higher individual recruiter production. Also, it is possible that the various services compete with each other for the target cohort with approximately equal determination thus canceling the apparent overall influence of the recruiters. It is also possible that the target cohort is not as easily influenced by recruiters as "lower quality" recruits, as the target cohort would seem to have a greater selection of civilian occupations. The individuals in the target cohort may have already made the decision to enlist based on economic factors prior to contact with a production recruiter. And, it is possible that recruiters really don't have a significant impact when compared to the impact of unemployment and compensation.

The studies discussed in Chapter Two found little significance between the numbers of production recruiters and the number of enlistments. Perhaps the services in general and the Navy in particular have passed the point of decreasing returns as far as recruiters are concerned. There may be some optimal level for the number of production recruiters such that additional production recruiters over this level are not beneficial in enlisting additional members of the target cohort. It may be more cost effective to invest in advertising than in additional recruiters. The area of costs and benefits of recruiters versus advertising is an area which deserves additional study.

The exclusion of the variables WRKFRCE, PERCUNE and UNEMRAT is not as discouraging. As evidenced in the regression models presented, when these variables where included, there was an adverse impact on the T-ratio for the variable UNEMPLD1. Since the values of the variable UNEMPLD are included in the variable WRKFRCE, and the values of the variables PERCUNE and UNEMRAT are constructed from the variable UNEMPLD, multicolinearity among these variables may be a factor, and is suggested by the regression results. The effects of unemployment and the change in unemployment appear well represented in the final regression equation without including these three additional variables.

## D. RESIDUALS EXAMINED.

The Durbin-Watson statistic for the regression was 1.52. As previously stated, a Durbin-Watson statistic between 1.5 and 2.5 normally indicates a lack of serial (auto) correlation for a data set of the size used in this study. With three independent variables and a sample size of 60, a Durbin-Watson statistic between 1.69 and 2.31 would assure no serial correlation in the residuals. The obtained statistic of 1.52 falls in the inconclusive range. Since this test is inconclusive, additional study is warrented.

The standardized residuals and the raw residuals were plotted in figures 4.1 and 4.2 The value of a standardized residual was determined by dividing the residual by its estimated standard deviation. Of particular interest here is any value outside +/- 2.00. In Figure 4.1 there are only two values that lie outside the specified limits. Since the overwhelming number of residuals lie well within these limits, no significant bias is indicated. In Figure 4.2, the residuals are plotted. The residual mean is -0.00058120 with a standard deviation of 7.89. Examing Figure 4.2, there is no obvious suggestion of a pattern in the data. However, the Durbin- Watson statistic of the final multiple regression model requires that further analysis be conducted to determine if serial correlation exists. In the following chapter, the residuals of the regression will be examined further. Combining the regression model developed in this chapter with an ARIMA process as described in chapter 3 would provide an improved model, assuming serial correlation in the residuals. If no serial correlation exists, then the regression model alone would prove to be the superior model.

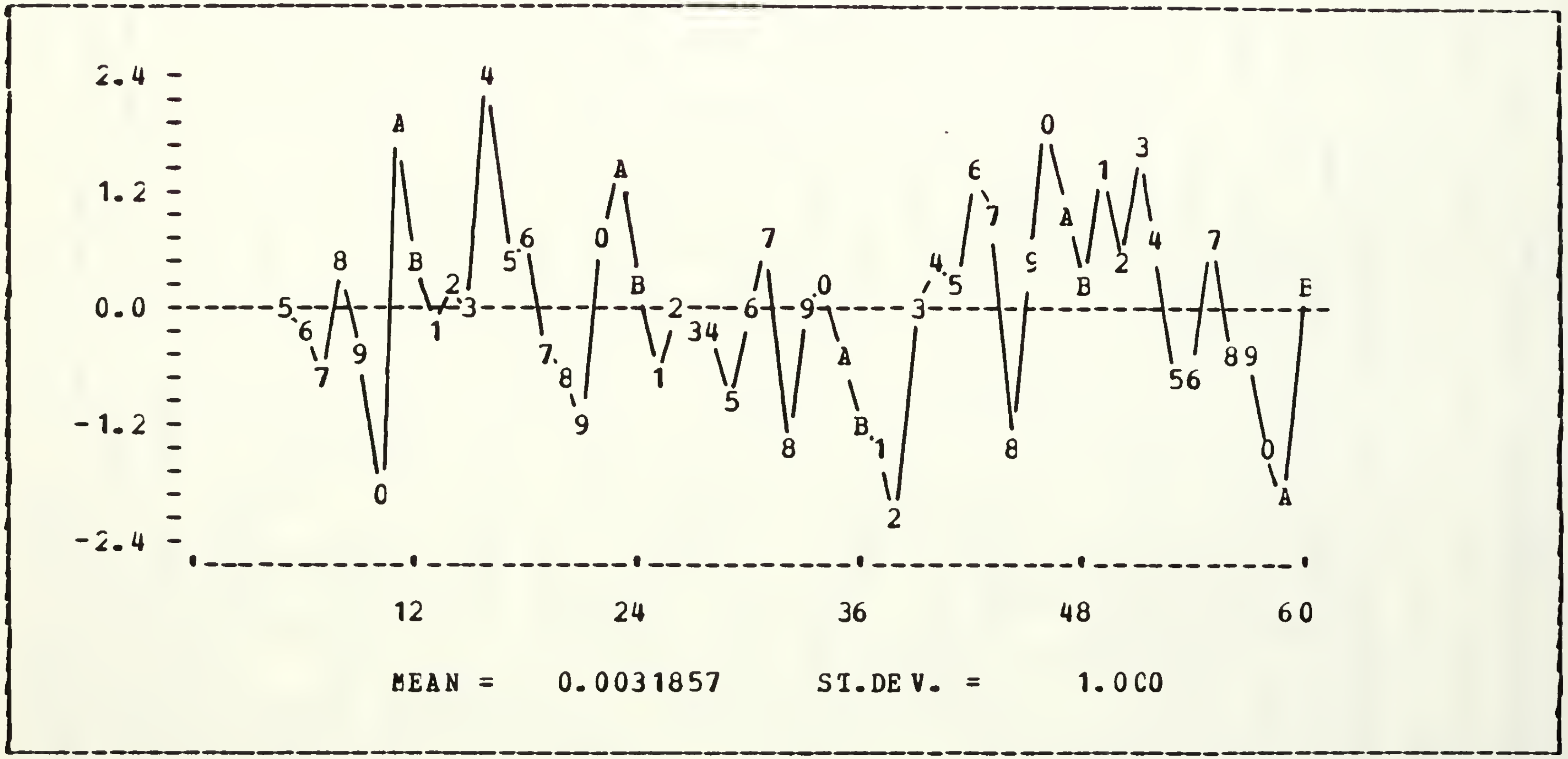

Figure 4.1 STANDARDIZED RESIDUALS.

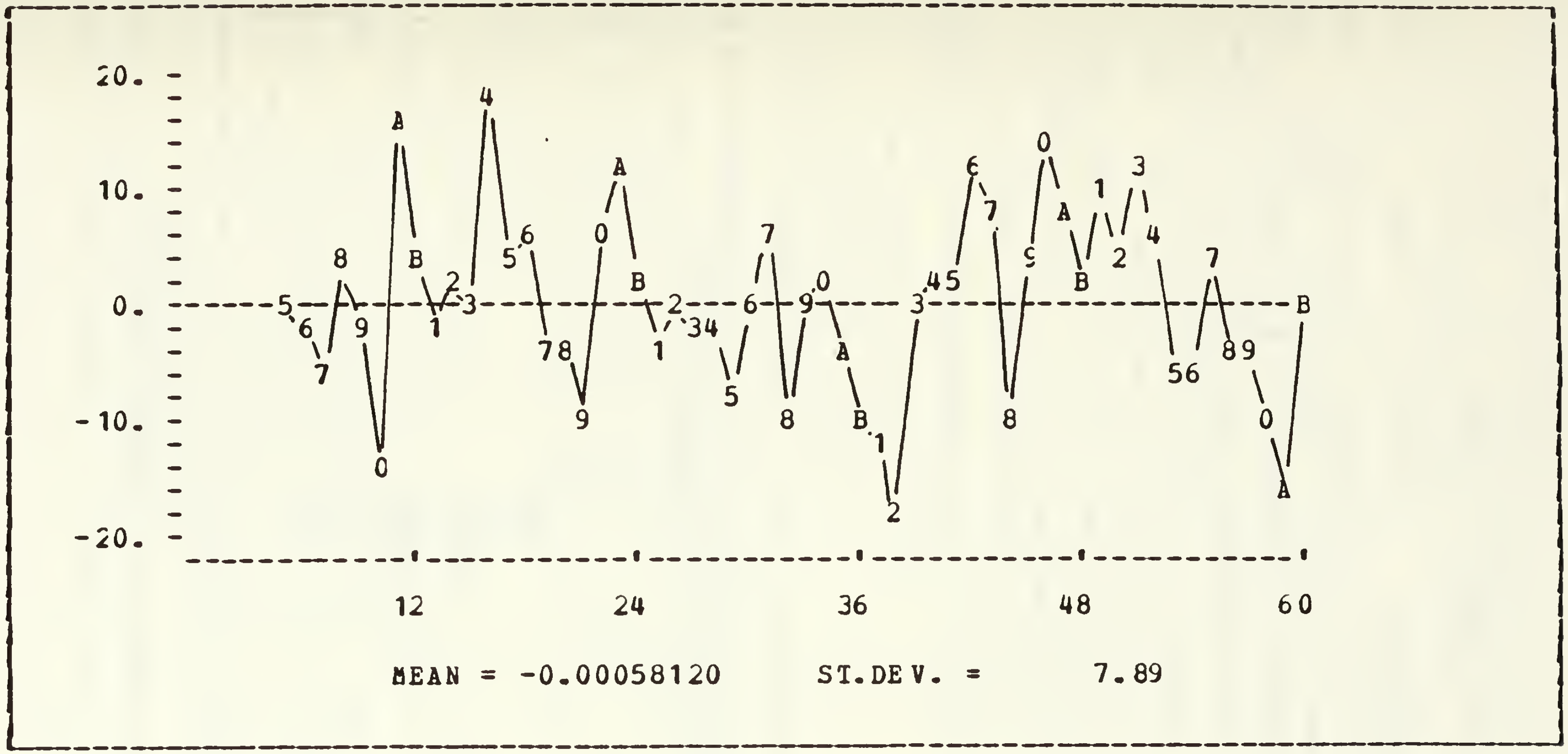

Figure 4.2 RESIDUALS.

# V. THE COMBINED MODEL

## A. COMBINED MODEL DEVELOPED

The multiple regression model developed in Chapter 4 satisfied all requirements except for the possibility of serial correlation in the residuals. In order to determine if in fact a serial correlation problem existed and, if so, to attempt to correct this problem, the residuals were examined further. The hypothesis was that if an ARIMA model could be developed for the residuals, then a serial correlation problem existed. However, this same model could in turn be applied as a correction to the regression model for more accurate forecasts.

```
            -0.6 -0.4 -0.2  0.0  0.2  0.4  0.6
              '----'----'----+----'----'----'
  1  0.239             '      XXXXXXX'
  2 -0.019             '      X      '
  3  0.101             '      XXXX   '
  4  0.012             '      X      '
  5  0.053             '      XX     '
  6  0.073             '      XXX    '
  7 -0.061             '    XXX      '
  8 -0.076             '    XXX      '
  9 -0.093             '    XXX      '
 10 -0.210             ' XXXXXX      '
 11 -0.110             '   XXXX      '
 12 -0.061             '    XXX      '
 13 -0.332            X'XXXXXXX      '
 14 -0.241             'XXXXXXX      '
 15 -0.007             '      X      '
 16 -0.132             '   XXXX      '
 17 -0.059             '     XX      '
                    -2SE          +2SE
```

Figure 5.1 RESIDUAL AUTOCORRELATIONS.

The multiple regression model residuals are displayed in Figure 4.2 The autocorrelations are plotted in Figure 5.1 . In this figure only the autocorrelation at lag 13 falls outside +/- 2 standard errors. However, no physical interpretation, such as seasonality, can be attributed to this spike, and it can be interperted as not being significant. Since there is no clear indication of a nonstationary pattern in the data, a white noise model was indicated as most appropriate. This model has the form:

$$Z_T = a_T \qquad \text{(eqn 5.1)}$$

where:

$Z_T$ = the residual value at time t

$a_T$ = a random shock at time t

This indicated that a model could not be developed for the residuals and, when the attempt was made to fit various ARMA models to the data, no ARIMA model could be found that was appropriate for the nondifferenced residual time series. This strongly suggests that no serial correlation existed for the residuals of the regression model developed in the previous chapter.

Reexamining Figure 5.1, there is a slight indication of a trend in the data if the general shape of the plot between lags 1 and 13 are observed. In order to explore this further, the residual time series was differenced once, with the resulting autocorrelations plotted in Figure 5.2 . Examining this figure, the immediate impression is that the data has been over differenced. This is suggested by the large negative spike at lag 1. Differencing a stationary series produces another stationary series. However, the model generated by the over differenced series will be more complicated than a model generated by a stationary series obtained with the minimum amount of differencing [Ref. 10]. At this point it was decided to continue with the attempt to construct a combined model, even though it was realized that the possibility was small of constructing a combined model which would prove superior to the regression model.

```
            -0.6 -0.4 -0.2  0.0  0.2  0.4  0.6
              '----'----'----+----'----'----'
   1 -0.331          X'XXXXXXX      '
   2 -0.249           'XXXXXXX      '
   3  0.138           '      XXXX   '
   4 -0.086           '    XXX      '
   5  0.013           '      X      '
   6  0.104           '      XXXX   '
   7 -0.080           '    XXX      '
   8  0.001           '      X      '
   9  0.066           '      XXX    '
  10 -0.142           '  XXXXX      '
  11  0.034           '      XX     '
  12  0.209           '      XXXXXX '
  13 -0.237           'XXXXXXX      '
  14 -0.095           '    XXX      '
  15  0.236           '      XXXXXXX'
  16 -0.130           '   XXXX      '
  17  0.008           '      X      '
                    -2SE          +2SE
```

Figure 5.2 DIFFERENCED RESIDUAL AUTOCORRELATIONS.

The partial autocorrelations of the differenced residual time series are displayed in Figure 5.3 . Based on a visual inspection of the autocorrelations and partial autocorrelations a second order autoregressive (AR2) model was initially selected for testing. However, the AR2 model proved not to be appropriate. Since any moving average (MAq) process can be rewritten to form an AR process, the next step was to test a MA2 model on the differenced time series. The tested model had the form:

$$Z_T - Z_{T-1} = \Delta Z_T = (1 - \theta_1 B - \theta_2 B^2)\epsilon_T \qquad \text{(eqn 5.2)}$$

where $Z_T$ is the residual value from the multiple regression model at time T and $\epsilon_T$ is the error term for the MA2 model.

```
        - -0.6 -0.4 -0.2  0.0  0.2  0.4  0.6
            '----'----'----+----'----'----'
 1 -0.331          X'XXXXXXX      '
 2 -0.402        XXX'XXXXXXX      '
 3 -0.147           '  XXXXX      '
 4 -0.245           'XXXXXXX      '
 5 -0.151           '  XXXXX      '
 6 -0.036           '     XX      '
 7 -0.071           '    XXX      '
 8 -0.029           '     XX      '
 9  0.035           '      XX     '
10 -0.120           '   XXXX      '
11 -0.091           '    XXX      '
12  0.141           '      XXXXX  '
13 -0.104           '   XXXX      '
14 -0.226           'XXXXXXX      '
15 -0.034           '     XX      '
16 -0.153           '  XXXXX      '
17 -0.122           '   XXXX      '
                  -2SE         +2SE
```

Figure 5.3 PARTIAL AUTOCORRELATIONS.

## TABLE III

## RESIDUAL MODEL EVALUATION

```
Residuals of model: Random
 Mean:                 0.34887
 Std Dev:              7.82
 Significance level
 for mean:             2.00
TYPE      ESTIMATE  ST. DEV.  T-RATIO
MA  1     0.6472    0.1324    4.89
MA  2     0.3060    0.1371    2.23
```

Table III suggests that the model is appropriate for the residual time series. The ARMA model for estimating future errors of the regression model then becomes:

$$\Delta Z_T' = (1 - .6472\ B - .306\ B^2)\, e_T \qquad \text{(eqn 5.3)}$$

Where $\Delta Z_T'$ is the estimated error of the multiple regression model at time t and $Z_T' = \Delta Z_T + Z_{T-1}$

where:

$Z_T'$ = predicted value of the residual at time t

$\Delta Z_T$ = change in the residual value from time t-1

$Z_{T-1}$ = value of the residual at time t-1

Letting $Y_T$ equal the predicted value of the multiple regression model alone, the predicted value of the combined model, $W_T$, then becomes:

$$W_T = Y_T + Z_T' \qquad \text{(eqn 5.4)}$$

However, in examining equation 5.3 and taking into consideration the standard deviation for the values of $\Theta_1$ and $\Theta_2$, it is conceivable that equation 5.3 could be factored as:

$$\Delta Z_T' = (1-B)(1+0.35B)\ \epsilon_T \qquad \text{(eqn 5.5)}$$

Cancelling out the differenced values, the equation becomes:

$$Z_T' = (1+0.35B)\,\epsilon_T \qquad \text{(eqn 5.6)}$$

Equation 5.6 indicates that the time series was over differenced and suggests using a MA1 model on the nondifferenced residual time series. However, this had previously been attempted was found not to be appropriate. To this point in the analysis of the residuals of the regression model, all tests conducted continue to indicate that the residuals are random and that no serial correlation exists. The only test remaining was to combine the regression model previously constructed with the MA2 model constructed above and to compare the results of each models forecasts.

## E. THE FORECAST COMPARISONS

Three models have been developed in order to forecast net new contracts signed. The best test of each model would have been to forecast some month or series of months subsequent to September 1983, the last month of the time series, and to compare the results. Due to the nonavailability of appropriate data this was not possible. As an alternative, the models were used to forecast the last five months of the time series, May 1983 to September 1983, since the results were known and the data required for forecasting with both the multiple regression and the combined model was available. The sequential forecasting method was utilized for all three models with results as contained in Table IV

As measured by the root mean squared error, the regression model is superior to the ARIMA model and slightly superior to the combined model. If the residuals of the multiple regression model were serially correlated, then the combined model should have corrected for this problem and produced forecasts superior to the multiple regression model. The forecast results serve to confirm that the multiple regression residuals were not serially correlated. The superiority of the regression model comes primarily from

## TABLE IV

## FORECAST COMPARISONS

| MONTH | ACTUAL | ARIMA | REGRESS | COMBINED |
|---|---|---|---|---|
| MAY 83 | 59 | 60.1 (+01.8%) | 63.3 (+07.3%) | 68.0 (+15.8%) |
| JUN 83 | 60 | 62.9 (+04.8%) | 63.4 (+05.7%) | 59.8 (-00.3%) |
| JUL 83 | 56 | 78.0 (+39.3%) | 67.0 (+19.6%) | 68.3 (+22.0%) |
| AUG 83 | 49 | 61.8 (+26.1%) | 64.6 (+31.8%) | 57.7 (+17.8%) |
| SEP 83 | 75 | 53.0 (-29.3%) | 74.9 (-00.1%) | 64.8 (-13.6%) |

SUM OF SQUARED ERRORS:
ARIMA MODEL : 1141.46
REGRESSION MODEL: 394.42
COMBINED MODEL : 412.06

ROOT MEAN SQUARED ERRORS (RMSE):
ARIMA MODEL : 16.90
REGRESSION MODEL: 9.93
COMBINED MODEL : 10.15

WHERE RMSE = $$\sqrt{\frac{\sum(Y_T - \hat{Y}_T)^2}{(n - 1)}}$$

$Y_T$ = actual value

$\hat{Y}_T$ = predicted value

n = 5 (number of observations)

the ability to relate sudden shifts in the dependent variable to measures of unemployment as exhibited by the predicted values for September 1983. The ARIMA process of the combined model has a dampening tendency on the predictions when there are sudden shifts in the variables. The regression process alone would then become the preferred model during a period of economic fluctuation because of the exhibited superior ability to capture these sudden shifts in accessions.

The difficulty in forecasting with the multiple regression model and the combined model is that one must also forecast future values of the change in percent of unemployment, the variable DELTAUN. Even with forecasted values of

DELTAON, the forecast horizon is limited to one month due to the one month lag for unemployment, the variable UNEMPID, unless future values for that variable are also forecasted. For any period beyond one month, the forecast for net contracts signed then depends on the accuracy of these two additional forecasts, decreasing the face validity of the prediction due to compounding negative effects. The attractiveness of the Box-Jenkins approach is that only the values of the time series are taken into consideration in the forecasting process. However, the basic assumption of continuity in the pattern of the data must hold generally true if the results are to be of value.

# VI. CONCLUSIONS

## A. SUMMARY

Three models utilizing two distinct analytical methodologies have been presented. The Box-Jenkins methodology was applied to a monthly time series of net enlistments in the Albuquerque, New Mexico recruiting district and a model of the underlying data patterns developed. A multiple regression model attempting to examine causal relationships was derived based on intuition and the statistical significance of the independant variables. A combined time series/causal model was developed treating the residuals from the regression model as an original time series and applying the Box-Jenkins technique to them. Forecasts were conducted with the three models and the results examined.

A comparison of the root mean squared error of the residuals of the three models indicated that the multiple regression model was superior to both the Box-Jenkins model and the combined model. Accuracy favored the multiple regression approach, however the need to develop forecasts for two principle independent variables limit its' usefulness in forecasting. A need to forecast extended periods would favor the Box-Jenkins approach since there does not exist a requirement to include the independent variables of the multiple regression model. Both the multiple regression model and the Box-Jenkins methodology can serve useful purposes when the inherent limitations of each are taken into consideration.

## E. IMPLICATIONS OF THE RESULTS

The multiple regression results suggested three variables were primarily responsible for the variation in the net number of contracts signed. These were the ordinal value of unemployment, the change in percent unemployed and the military / civilian pay ratio. Of these three variables, the Department of Defense (DOD) exerts only a partial influence over the military/civilian pay ratio. As alluded to previously, no single measure of the military/civilian pay ratio can be justified as a "best" measure of this relationship. The one presented in this study was felt to be an adequate estimation of how young men making an occupational choice view the relationship between military and civilian compensation. This ratio did not take into account such forms of compensation as medical benefits, enlistment bonuses, commisary and exchange privileges, special pays, and other benefits. Each individual places different values on these additional forms of compensation depending on his/her own needs and desires. It may be that these other forms of compensation provide the marginal benefit that sway a majority of enlistees towards an occupation in the military. The effects of these additional forms of compensation have been the focal point for many studies and their effects deserve continued research.

As for unemployment and the change in percent unemployed, little can be done by DOD to influence these variables. Indeed, it is unreasonable to assume that anyone would desire to place the economy of the nation in peril simply to ease recruiting short falls. However, it is clear that general economic factors play a pivotal role in the occupational choice process and that the effects of changes in the economic indicators can have an immediate impact. A sudden increase in civilian job market opportunities for the target cohort would have an immediate and adverse impact on Navy recruiting. During periods of general economic improvement, more resources will be required to obtain similar numbers of high quality enlistees than during a period of general economic decline.

Remaining unexplained in the analysis is the shift in the time series from apparent seasonality over the first two thirds of the series to apparent nonseasonality over the last third of the series. Seasonality in recruiting with peak months in August and January can most easily be explained by the school year. Intuitively, a young man would not desire to graduate from high school in June and directly enter military service. On the average, one would expect him to desire to remain among his friends for the Summer months, entering the service at the end of Summer when friends either return to school or enter the job market. The peak month of January can be intuitively explained by the potential recruits desire to remain among family and friends during the holiday season prior to entering the service. What is not readily explained is the virtual absence of this seasonality over the last third of the time series. Remembering that the dependent variable is contracts signed and not accessions, what may explain the change in the data pattern is a change in the quota system. Utilizing the DEP pool, the potential recruit is currently able to sign a contract with the Navy and delay entry into the service for a period of up to one year. This may have the effect of dampening the seasonal pattern exhibited by the first two thirds of the time series. However, this is pure conjecture as there was insufficient data available to conduct further analysis or draw any definite conclusions.

## C. RECOMMENDATIONS FOR FUTURE STUDY

The models presented in this study should be refined and updated. The 60 data point time series utilized is too brief to accurately depict cyclic flucuations in the data set. The time series should be expanded as additional data points become available. Estimates from models developed from time series of adequate length, in excess of 100 data points, could prove beneficial in allocating quotas and recruiting resources. Regression analysis, examining causal relationships on a recruiting district level, should continue in order that a better understanding of the effects that local economics have on the supply of potential enlistees can be obtained. One area of potential intrest may be the application of leading indicator models, an extension of the Box-Jenkins methodology, to the problem of predicting the supply of recruits.

Due to lack of sufficient available data, several refinments in this study which the author feels are important could not be made. First, in the area of unemployment, an accurate breakdown by sex, age, and ethnic group by recruiting district would have been of significant benefit. To make an appreciable improvement in the understanding of the interaction of local economic conditions on the supply of potential enlistees this data will be necessary for future studies. Some sort of working agreement with the Department of Labor; Bureau of Labor Statistics would be necessary in order to obtain the data in a useful form. A restructing of the recruiting districts would make data gathering easier. A realignment along state boundries would make close coordination with state governments more readily avialable. There could be a cooperative effort between the state unemployment office and the recruiting district. Although some states would be reluctant to act as a recruiting agency for the military, the central theme would be to find employment for the states young people to the benefit of the state and the Navy.

As previously discussed, the lack of sufficient data concerning quotas proved a drawback. There are three measures of recruiting effort over which the Navy has complete control which would seem to be inseperable in their effects. These are the number of production recruiters, quotas, and local advertising. To study any one of these, or to include any one of these in a study to the exclusion of the others would seem to be of little value. Records of adequate length and detail should be kept in order to study the long term effects of these factors and specifically how they interact with each other. It may be beneficial to the recruiting effort to decrease the number of production recruiters while increasing goals and local advertising. However, unless the data is available to study, or pilot programs are initiated, there can be no clear demonstration of the interrelationships of these various recruiting efforts. Without strong evidence of the interrelationships between these three efforts, no study of the supply of first term enlistees can be considered complete.

Another interesting area which should be examined is Delayed Entery Program (DEP) attrition. It would be interesting to determine if an improved job market corresponded to an increase in the number of contract signers attempting to nullify their contract. In some cases a new recruit has the potential to remain in the DEP pool for up to one year. The economic opportunities for this potential recruit could vary considerably during this years time, and during a general improvement in the economy, civilian job opportunities could become available to the cohort member that did not exist when he/she became part of the DEP pool. The erosion of the DEP pool should be studied as a potential problem area.

Of particular benefit would be a regional study encompassing accessions into all four branches of the military and the Coast Guard. A study of this type would permit the examination of the interaction of the different recruiting efforts. This would assist in determining if an increase in the recruiting efforts of any one service served to increase the total number of accessions, or merely drew away potential recruits from one of the other services. Additionally, by comparing the regional economy to total military accessions for the region, a clearer understanding of the effects of changing economic conditions could be obtained.

# APPENDIX A

# PRIMER ON TIME SERIES ANALYSIS

## A. TIME SERIES ANALYSIS

Except where otherwise noted, this appendix is based on the works of S. Makridakis and S.C. Wheelwright. A time series is a collection of observations made sequentially in time. Examples occur in a variety of fields from physics to physiology and methods of analyzing time series constitute an important area of statistics. Statistical techniques for analyzing time series range from the straight forward to the very sophisticated. However, traditional means of time series analysis are primarily concerned with decomposing a series into the basic components of trend, seasonality, cyclic changes and other fluctuations.

The first step in analyzing a time series is to plot the observations against time. Figure A.1 is a time series plot of the sales figures for a certain engineering company over successive months [Ref. 11]. This plot can be used to obtain simple descriptive measures of the main properties of the series. For example, looking at Figure A.1, it can be seen that there is a regular seasonal effect with sales 'high' in the winter and 'low' in the summer. The graph suggests an upward trend in annual sales. For some time series, the variation is dominated by such 'obvious' features, and a fairly simple model may be perfectly adequate to describe the variation in the time series. For other time series, more sophisticated techniques will be required to provide adequate analysis.

When observations are taken on two or more variables, it may be possible to use the variation in one time series to

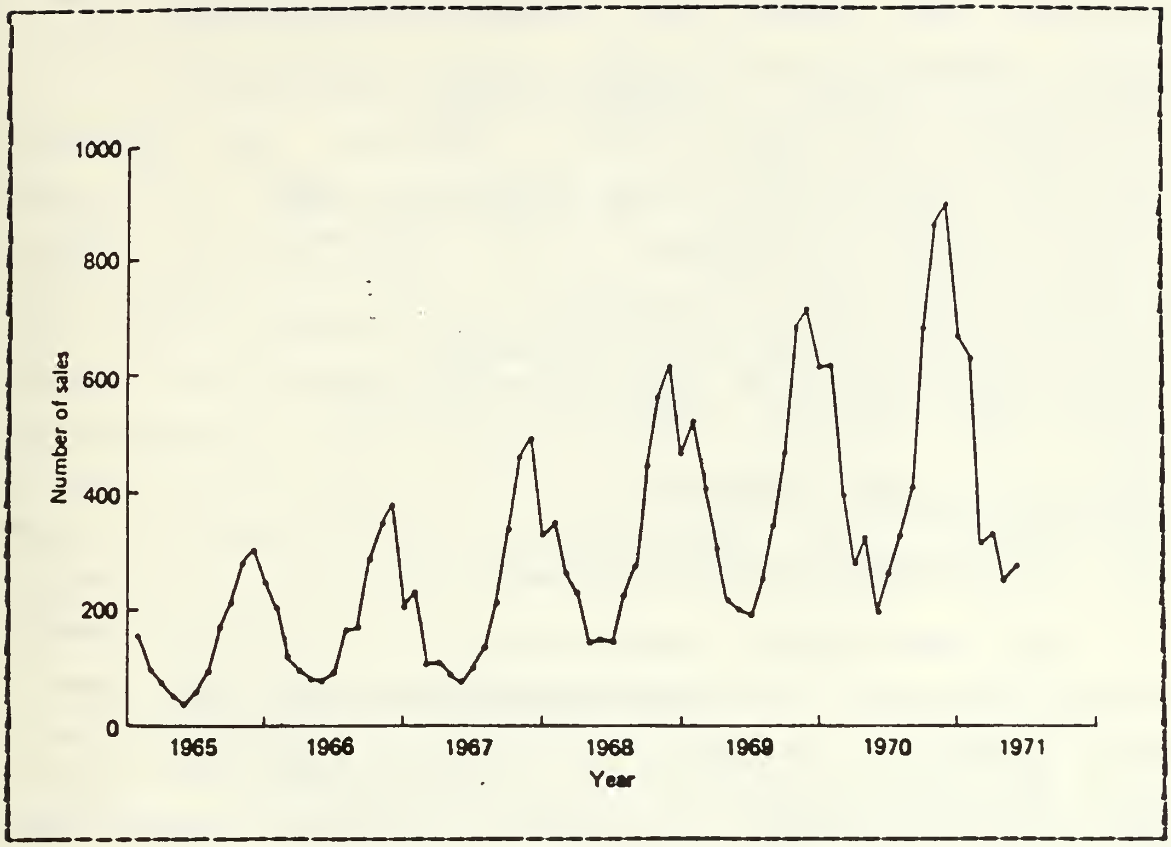

Figure A.1 Monthly Sales.

explain the variation in another time series. This may lead to a deeper understanding of the underlying causal relationships in a process and permit accurate forecasts of future values of the variable of interest. This may in turn aid in the control of that future value.

The ability of a given technique to forecast effectively in a specific situation depends largely on accurately identifying the patterns underlying the data and selecting the proper technique to handle them. All time series analysis techniques assume that the patterns underlying the data are constant over two periods; the period over which the data was collected, and the period of the forecast. However, different techniques are available to fit a wide variety of situations. The factors that need to be considered when selecting a model are as follows:

1. The time horizon for decision making
2. The pattern of the data
3. Type of model desired: time series or causal
4. The value of the forecast
5. The accuracy that is required
6. The complexity that can be tolerated
7. The availability of historical data [Ref. 8]

## E. THE BOX-JENKINS METHODOLOGY

### 1. The Advantages of Box-Jenkins

The Box-Jenkins methodology is an efficient and practical procedure for handling time series and other forecasting situations in which a variety of complex patterns exist. This methodology can handle complex patterns of data using a relatively well specified set of rules that do not require that a model be chosen on the basis of an analyst's experience, intuitive ability or theory.

Box-Jenkins is the most general method of approaching time-series forecasting. There is no need to assume initially some fixed pattern to date. The approach begins by assuming a tentative pattern that is fitted to the data so that the error will be minimized. It additionally provides explicit information to enable the user to judge whether the pattern tentatively assumed is correct for the situation under study. If so, the forecast can be developed directly and, if not, the Box-Jenkins approach provides further clues for identifying the correct pattern. This procedure allows the user to arrive at a forecasting model that achieves optimization in terms of the basic pattern and minimizes the forecasting error. The user is also supplied with statistical information on the accuracy of the forecasts.

### 2. The General Approach

In describing their approach, Box and Jenkins have developed the schematic diagram shown in figure A.2 [Ref. 12]. This approach divides the problem into three stages. In stage one, a specific model is suggested as the forecasting method best suited to that situation. In stage two, that suggested model is fitted to the historical (time series) data and the suggested model is checked to determine its adequacy. If the model is not adequate, the analyst returns to stage one, and an alternative model is proposed. When an adequate model is identified, the development of a forecast for some future time period is conducted in stage three.

### 3. The Role of Autocorrelation

An autocorrelation coefficient is similar to a correlation coefficient except that it describes the association among values of the same variable but at different time periods. The autocorrelation among successive values of the data is a key tool in identifying the most appropriate model corresponding to the basic pattern of the data. Correlation implies nothing about a change in one variable causing a change in the other variable.

To further demonstrate, we can construct an artificial variable from another variable by changing the time origin of the data. For example, dropping the first value of 'A' and letting the second value be the starting value of 'B', See figure A.3 . In this example variables 'A' and 'B' can be treated as two separate and distinct variables even though they came from the same data set. In this example, 'B' has a time lag of one period from 'A'. This same approach can be expanded to create additional data sets utilizing as many time lags is as deemed necessary for identifying the appropriate model.

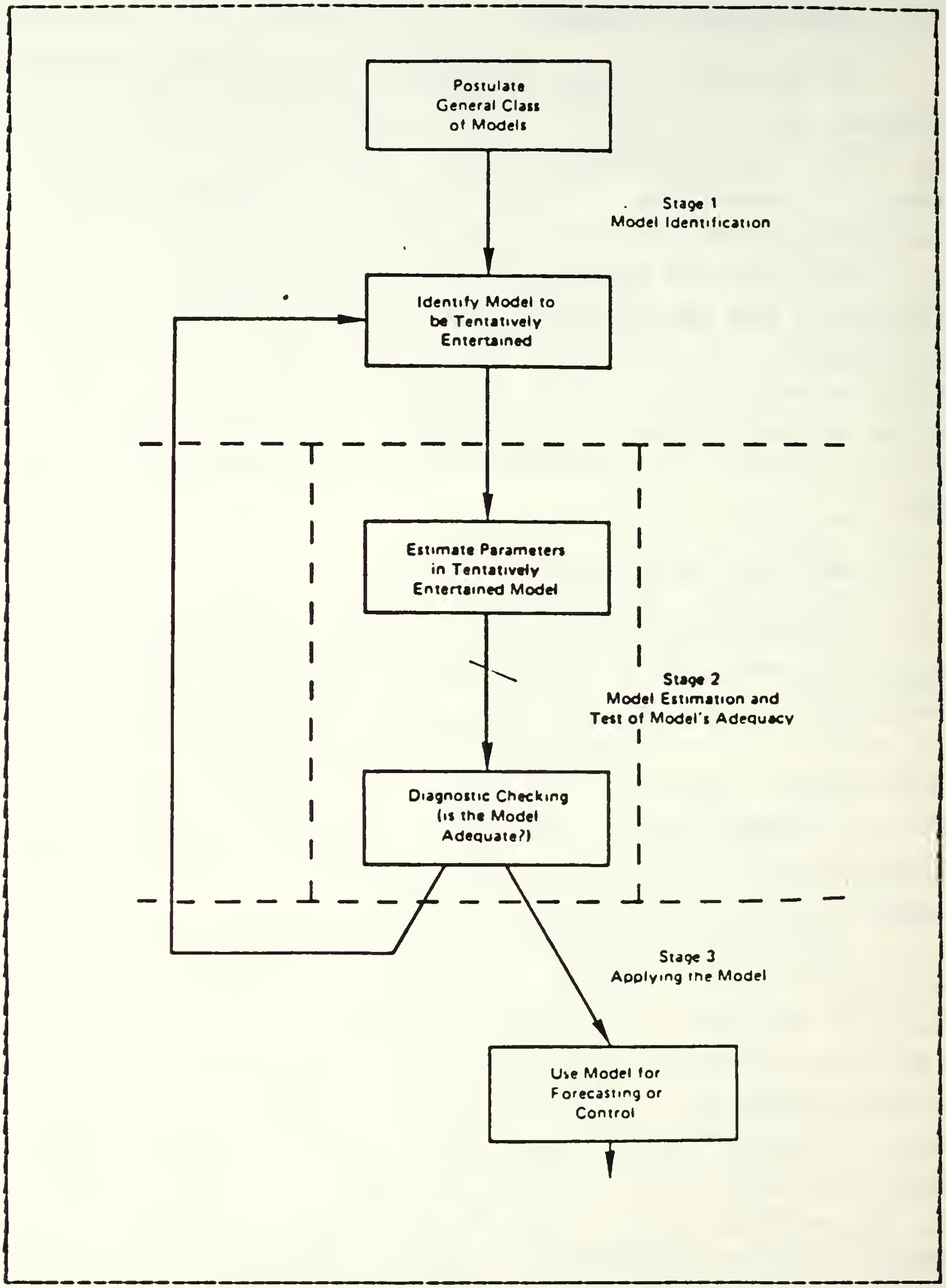
Postulate General Class of Models
Stage 1 Model Identification
Identify Model to be Tentatively Entertained
Estimate Parameters in Tentatively Entertained Model
Stage 2 Model Estimation and Test of Model's Adequacy
Diagnostic Checking (is the Model Adequate?)
Stage 3 Applying the Model
Use Model for Forecasting or Control

Figure A.2 Box-Jenkins Method.

| A | B |
|---|---|
| 6 | 8 |
| 8 | 5 |
| 5 | 3 |
| 3 | 1 |
| 1 | 4 |
| 4 | 5 |
| 5 | |

Figure A.3 Lagged Variables.

We can consider variables 'A' and 'B' as two variables and calculate their correlation coefficients. A coefficient of .80 between 'A' and 'B', for example, would imply that successive values of 'A' with one period (lag) between them are positively correlated with each other and tend to move in the same direction. Similarly, a coefficient of -.70 between 'A' and 'B' would indicate that successive values of 'A' lagged once are negatively correlated and tend to move in opposite directions. However, since variable 'B' is actually derived from variable 'A', such an association is called auto-(self-) correlation.

Autocorrelations provide significant clues about the underlying pattern of a data set. In a set of completely random data the autocorrelations among successive values will be close to zero, but data values of strong seasonal and/or cyclical character will be highly correlated. Figure A.4 [Ref. 13] for instance, presents the autocorrelations of different time lags of monthly temperature in Paris. These autocorrelations reveal a strong seasonal pattern.

```
              -1.0 -0.8 -0.6 -0.4 -0.2  0.0  0.2  0.4  0.6  0.8  1.0
                +----+----+----+----+----+----+----+----+----+----+
   1    0.802                            XXXXXXXXXXXXXXXXXXXXX
   2    0.440                            XXXXXXXXXXXX
   3   -0.021                            X
   4   -0.465                 XXXXXXXXXXXX
   5   -0.771         XXXXXXXXXXXXXXXXXXXX
   6   -0.869      XXXXXXXXXXXXXXXXXXXXXXX
   7   -0.742          XXXXXXXXXXXXXXXXXXX
   8   -0.423                 XXXXXXXXXXXX
   9   -0.001                            X
  10    0.437                            XXXXXXXXXXXX
  11    0.741                            XXXXXXXXXXXXXXXXXXXX
  12    0.857                            XXXXXXXXXXXXXXXXXXXXXXX
  13    0.714                            XXXXXXXXXXXXXXXXXXX
  14    0.383                            XXXXXXXXX
  15   -0.020                            X
  16   -0.422                  XXXXXXXXXXX
  17   -0.693             XXXXXXXXXXXXXXXX
  18    0.776                            XXXXXXXXXXXXXXXXXXXX
  19    0.679                            XXXXXXXXXXXXXXXXX
  20    0.400                            XXXXXXXXXXX
  21   -0.010                            X
  22    0.389                            XXXXXXXXXXX
  23    0.670                            XXXXXXXXXXXXXXXX
  24    0.777                            XXXXXXXXXXXXXXXXXXXX
```

Figure A.4 Monthly Temperature in Paris.

It is this type of information gained from autocorrelations that can be utilized by the Box-Jenkins approach to identify the optimal forecasting model. Of particular interest is that the analyst needs to know nothing of the data set or its patterns to obtain its autocorrelation coefficients. These coefficients can be used to describe the data set and assist in identifying a tentative model to be fitted to the data.

What Figure A.4 implies is that temperature of months twelve periods apart are highly correlated. Although this is basically intuitive, if this were not previously known the autocorrelations would be of significant benefit in suggesting an appropriate model to describe the data pattern [Ref. 13].

### 4. Box-Jenkins Model Types

The Box-Jenkins methodology postulates three general classes of models that can generally describe any type or pattern of time series data:

a. Autoregressive (AR)

b. Moving Average (MA)

c. Mixed Autoregressive-Moving Average (ARMA)

An autoregressive model (AR) has the form:

$$Y_T = \Phi_1 Y_{T-1} + \Phi_2 Y_{T-2} + \Phi_3 Y_{T-3} + \ldots + \Phi_p Y_{T-p} + e_T \qquad \text{(eqn A.1)}$$

where $Y_T$ is the independent variable, high quality recruits, and $Y_{T-1}$, $Y_{T-2}$, $Y_{T-3}$, ...., $Y_{T-p}$ are "independent" variables. In this case the independent variables are values of the same variable, but of previous periods (t-1,t-2,t-3,...t-p).

Finally $\epsilon$ is the error or residual term that represents random events that are not explained by the model. The residuals (errors) of the model should be white noise, that is they should have a mean of zero, a constant variance and be uncorrelated over time.

The model described is autoregressive because it is similar to the regression equation

$$Y=a+b_1X_1+b_2X_2+b_3X_3+\ldots+b_pX_p+\epsilon_T \qquad \text{(eqn A.2)}$$

except that:

$$X_1=Y_{T-1},\ X_2=Y_{T-2},\ X_3=Y_{T-3},\ldots,X_p=Y_{T-p}$$

and thus the independent variables are only lagged values of the dependant variable with time lags of 1, 2, 3,..., p periods. The autoregression model is similar in function and form to the regression equation. However it is not appropriate to describe all possible underlying data patterns in time series analysis. Thus, the Box-Jenkins approach also considers two other classes of models.

The Moving Average (MA) model has the form:

$$Y_T=\epsilon_T-\theta_1\epsilon_{T-1}-\theta_2e_{T-2}-\theta_3e_{T-3}-\ldots-\theta_qe_{T-q} \qquad \text{(eqn A.3)}$$

where $\epsilon_T$ is the error or residual and $e_{T-1}$, $e_{T-2}$, $e_{T-3}$, ..., $\epsilon_{T-q}$ are previous values of the error. This implies that the dependant variable $Y_T$, depends on previous values of the error term ($e_{T-1}$, $e_{T-2}$, $e_{T-3}$, ..., $e_{T-q}$) rather than on the variable itself. The future value of high quality enlistments could be predicted by utilizing the error of each of several past predictions. In the same manner that autocorrelation among successive values of Y can be examined, the autocorrelation among the successive values of the residuals can also be examined.

The third class of model considered by the Box-Jenkins methodology is a mixed model. The best description of the pattern of data may be provided by a mixed process of AR and MA elements. The general mixed model has the form:

$$Y_T = \Phi_1 Y_{T-1} + \Phi_2 Y_{T-2} + \dots + \Phi_p Y_{T-p} + e_T - \Theta_1 e_{T-1} - \Theta_2 e_{T-2} - \dots - \Theta_q e_{T-q} \qquad \text{(eqn A.4)}$$

It is evident that this model is simply the AR and MA models combined. It suggests that future values of high quality recruits depend on both past values of high quality enlistments and the errors between forecasts and actual values.

### 5. Identifying a Tentative Model

It is possible to suggest some specific ARMA (p,q) model by examining the autocorrelation coefficients and a similar set of parameters, the partial autocorrelation coefficients. Partial autocorrelation coefficients are analogous to autocorrelation coefficients in that they indicate the relationship of the values in a time series to various lagged values of the same series. However, they differ from autocorrelations in that they are computed for each time lag after removing the effect of all other time lags in the given time lag and on the original series. In essence, they show the relationship that exists for varying time lags [Ref. 8].

Combinations of autocorrelation and partial autocorrelation coefficients, in the absence of randomness, can reveal the exact ARMA model. Randomness complicates the task because it influences the values of the autocorrelation coefficients and may cause them to deviate from their "true" pattern. This makes model identification more difficult, but generally there is enough information available to select an appropriate model. Even if there is a mistake at this point in the analysis, it will be found when a test of the model is conducted. Figures A.5 through A.9 demonstrate the behavior of the theoretical autocorrelations (ACs) and partial autocorrelations (PACs) for each model, where "MA" denotes a moving average model, "SMA" denotes a seasonal moving average model, "AR" denotes an autoregressive model and "SAR" denotes a seasonal autoregressive model. [Ref. 10]

Thus in order to forecast a time series, the autocorrelations and partial autocorrelations must be computed first. Sometimes the pattern of the computed autocorrelations and partial autocorrelations can be easily classified as one of the theoretical ones described below. The identification of an appropriate model is then relatively easy . Other times, some free association and intuitive judgement is required to be able to infer a pattern from the autocorrelations, or more than one pattern may be suggested. In such instances, a choice can be made based on goodness of fit and number of parameters involved. Once a tentative model has been made, the next step is to estimate the parameters.

### 6. Estimating the Parameters

Assuming that the tentative model is an ARMA (1,1) its' mathematical form is

$$Y_T = \Phi_1 Y_{T-1} + e_T - \theta_1 \epsilon_{T-1} \qquad \text{(eqn A.5)}$$

in order to utilize this model, the value of $\Phi$ and $\theta$ must be estimated. The general approach is to start with some estimated initial values for $\Phi$ and $\theta$ and then modify them by small steps while observing the sum of the squared errors (SSE). This allows the direction of change in $\Phi$ and $\theta$ that result in the smallest SSE to be determined. Eventually, the $\Phi$ and $\theta$ corresponding to the minimum SSE are found and used as the final estimates for the model. The next step is to test the adequacy of the model.

### 7. Testing the Model's Adequacy

If the model is adequate, the residuals (differences) between the time series values and those estimated by the model must be random (white noise). The autocorrelation coefficients for these residuals are examined. If none of the autocorrelation coefficients of the residuals are significantly different from zero (plus or minus two standard errors), the errors are assumed to be white noise and the model is adequate. If the autocorrelations are not random, the analyst must return to step two and select another model.

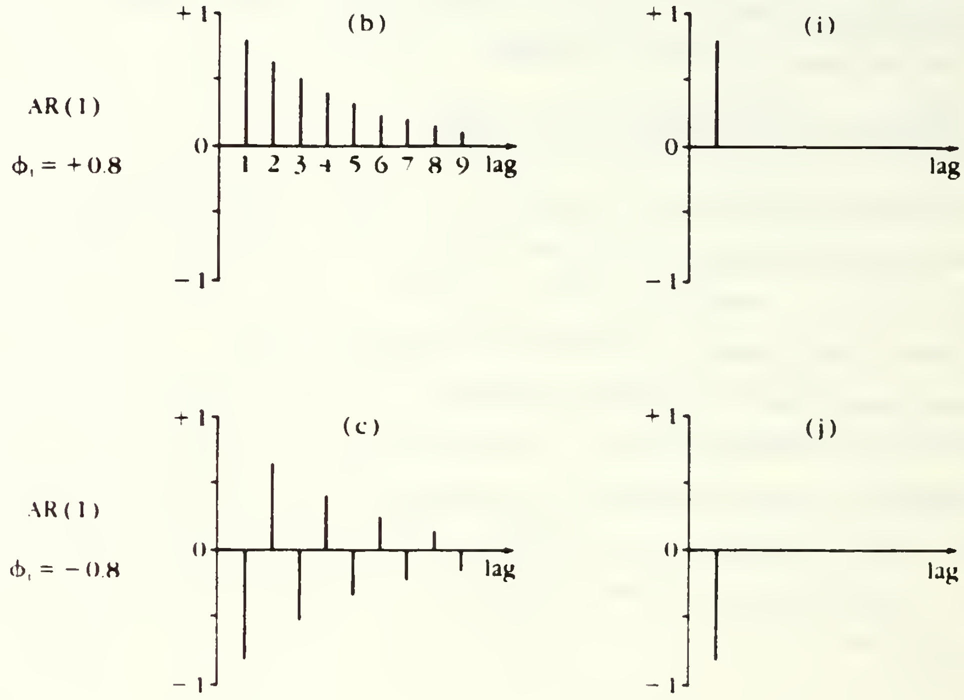

Figure A.5 AR (1) Model ACs and PACs.

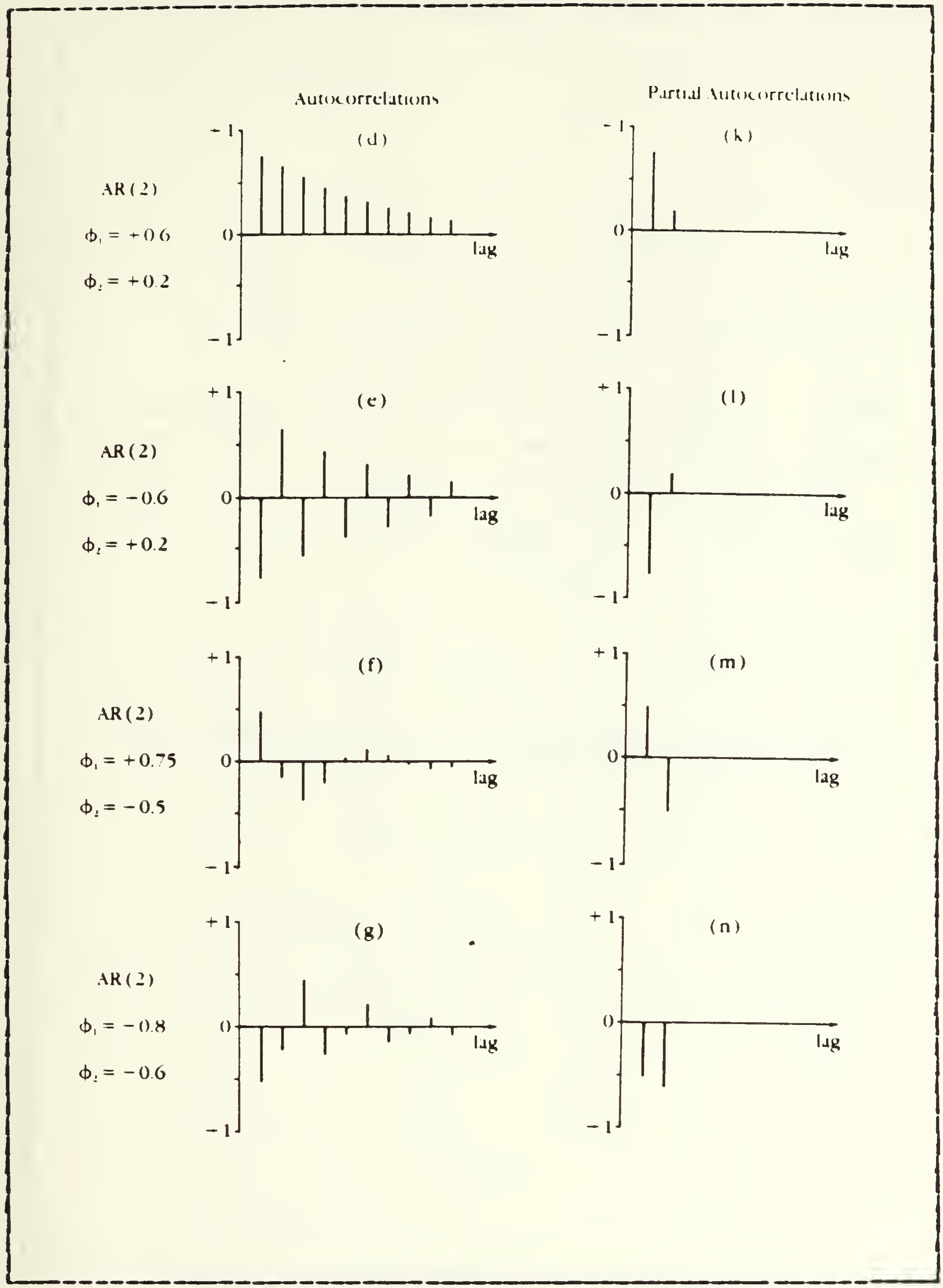

Figure A.6 AR (2) Model ACs and PACs.

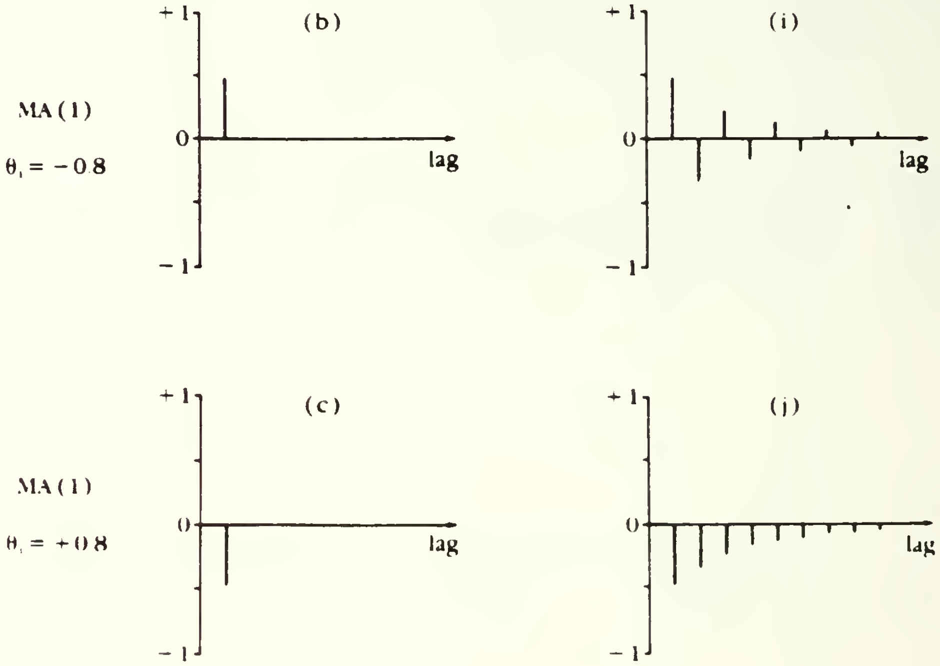

Figure A.7 MA (1) Model ACs and PACs.

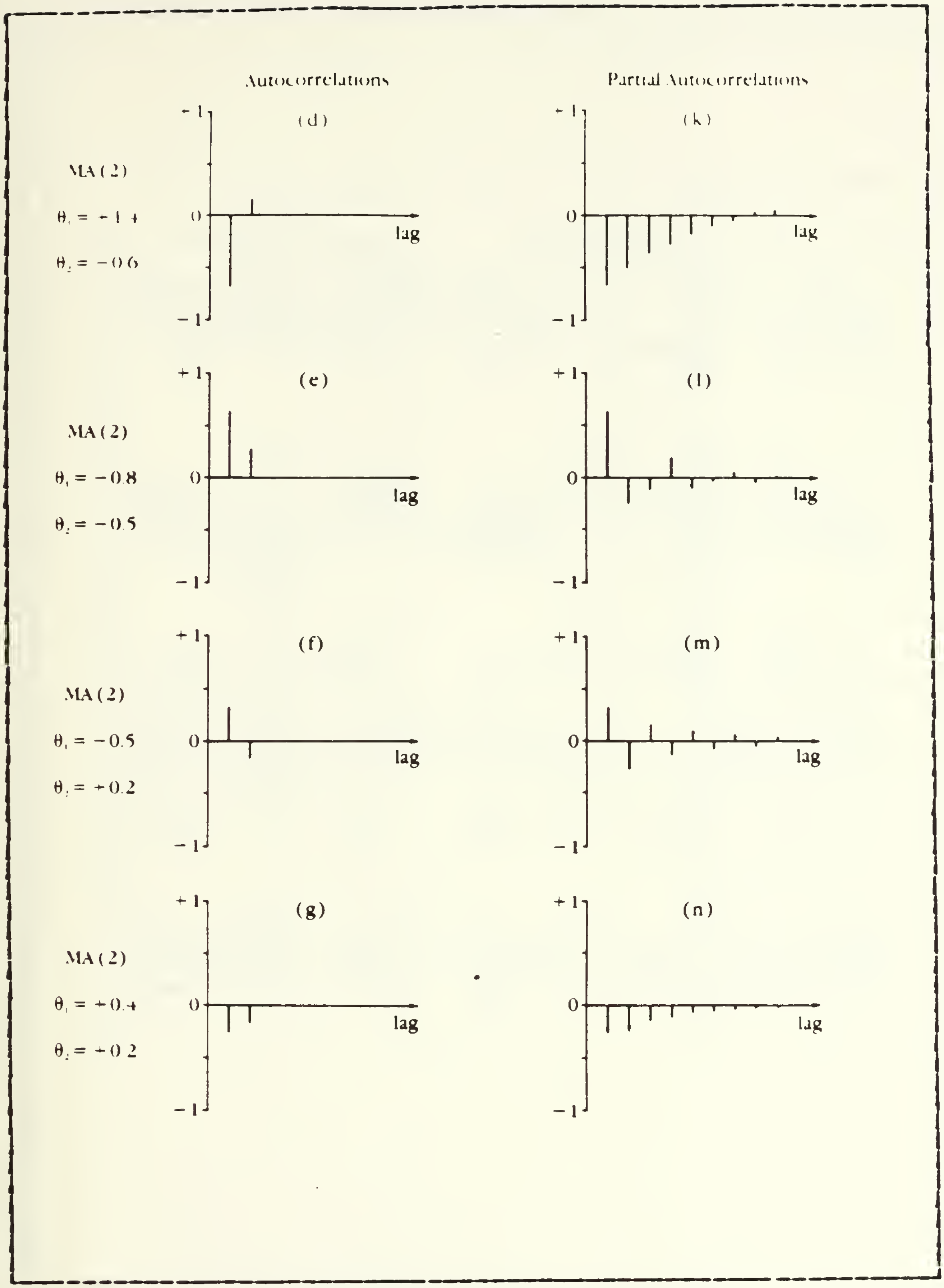

Figure A.8 MA (2) Model ACs and PACs.

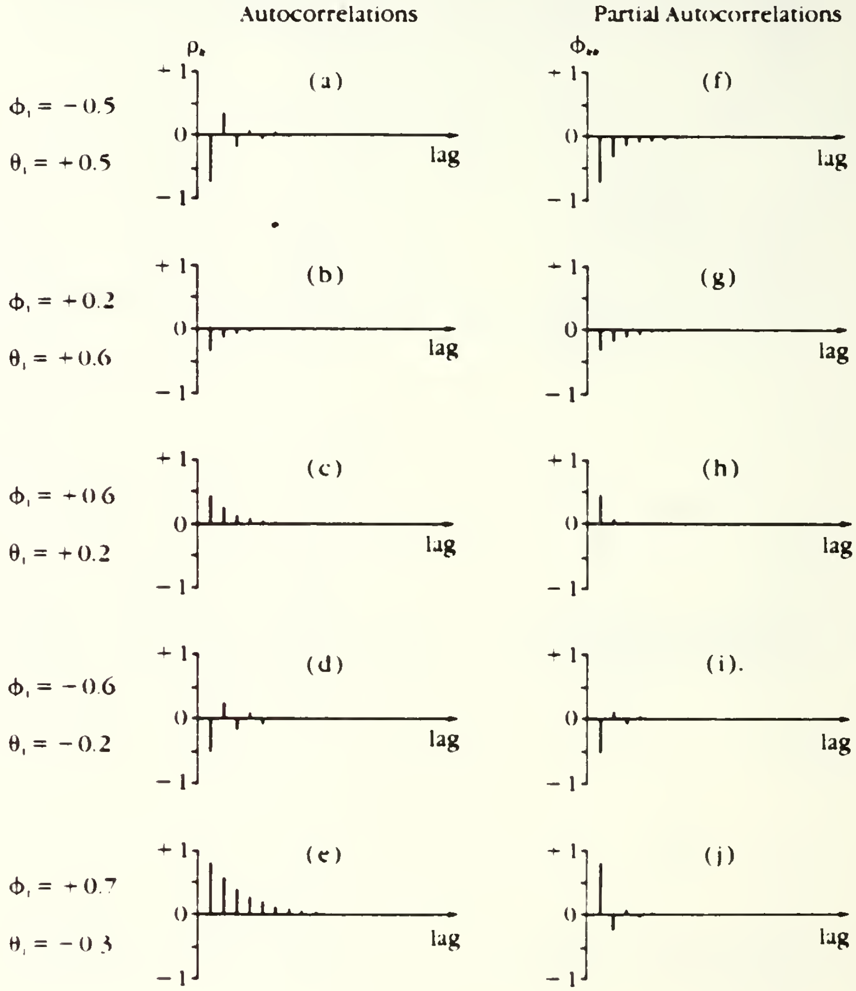

Figure A.9 Mixed Arma (1,1) Model ACs and PACs.

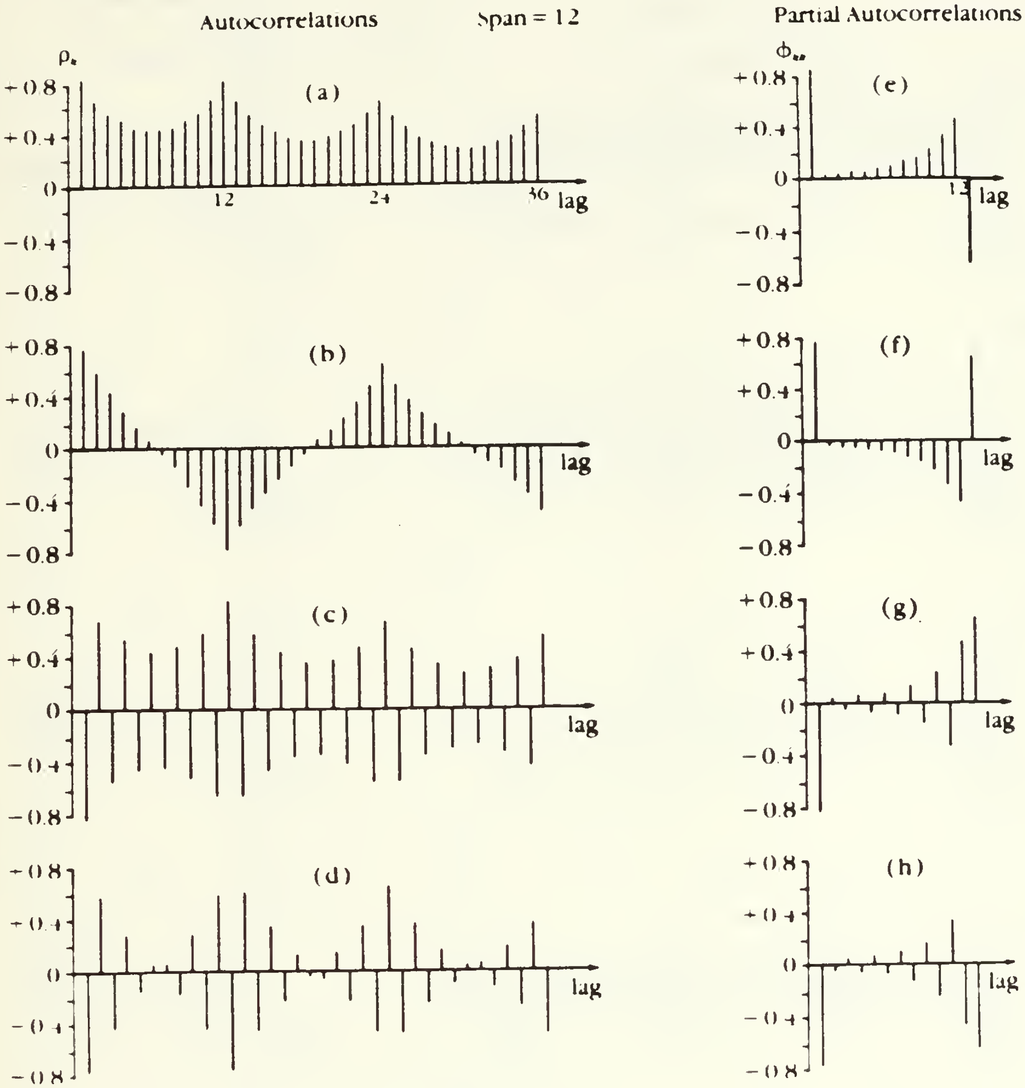

Figure A.10 AR(1) X SAR(1) Seasonal Model ACs and PACs.

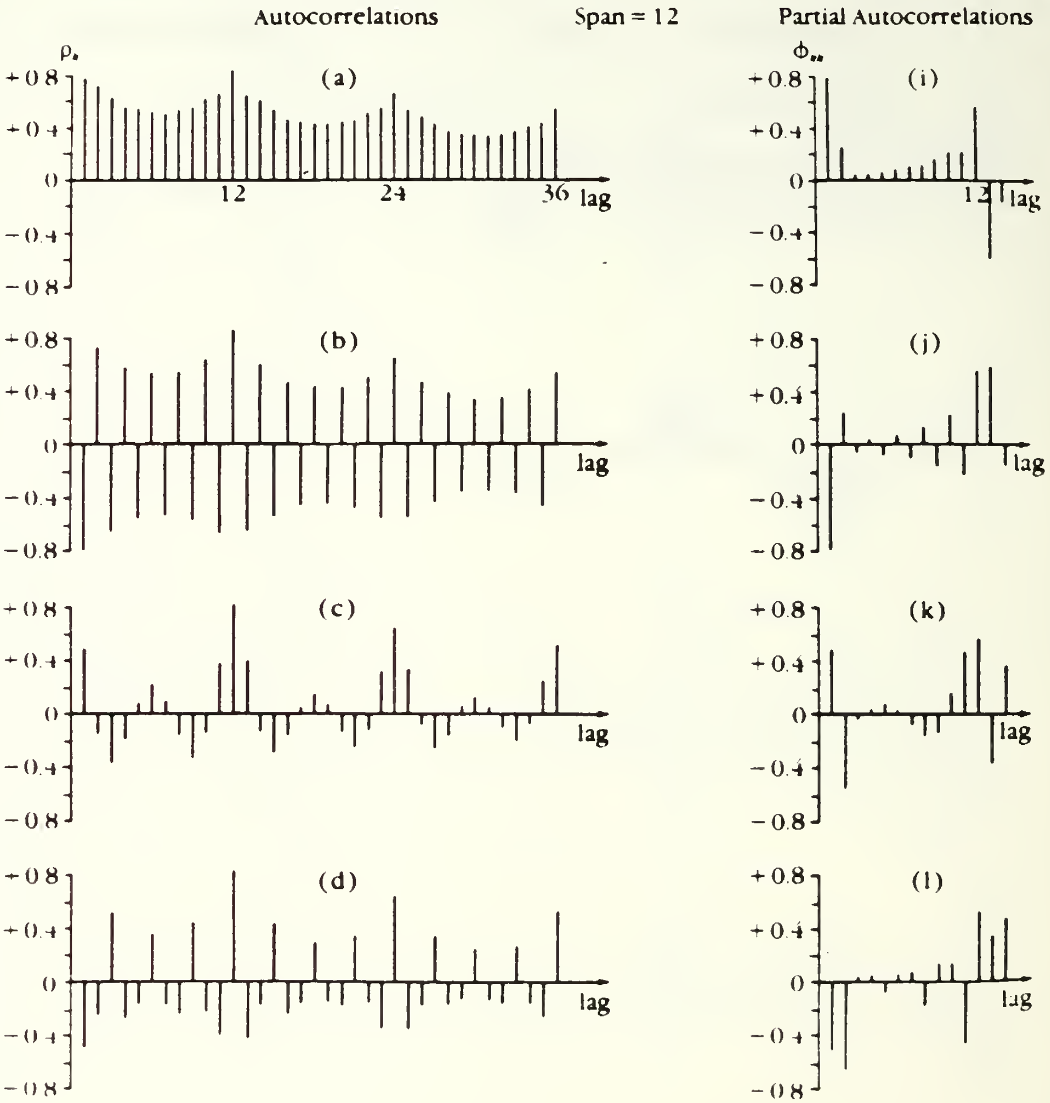

Figure A.11 AR(2) X SAR(1) Seasonal Model ACs and PACs.

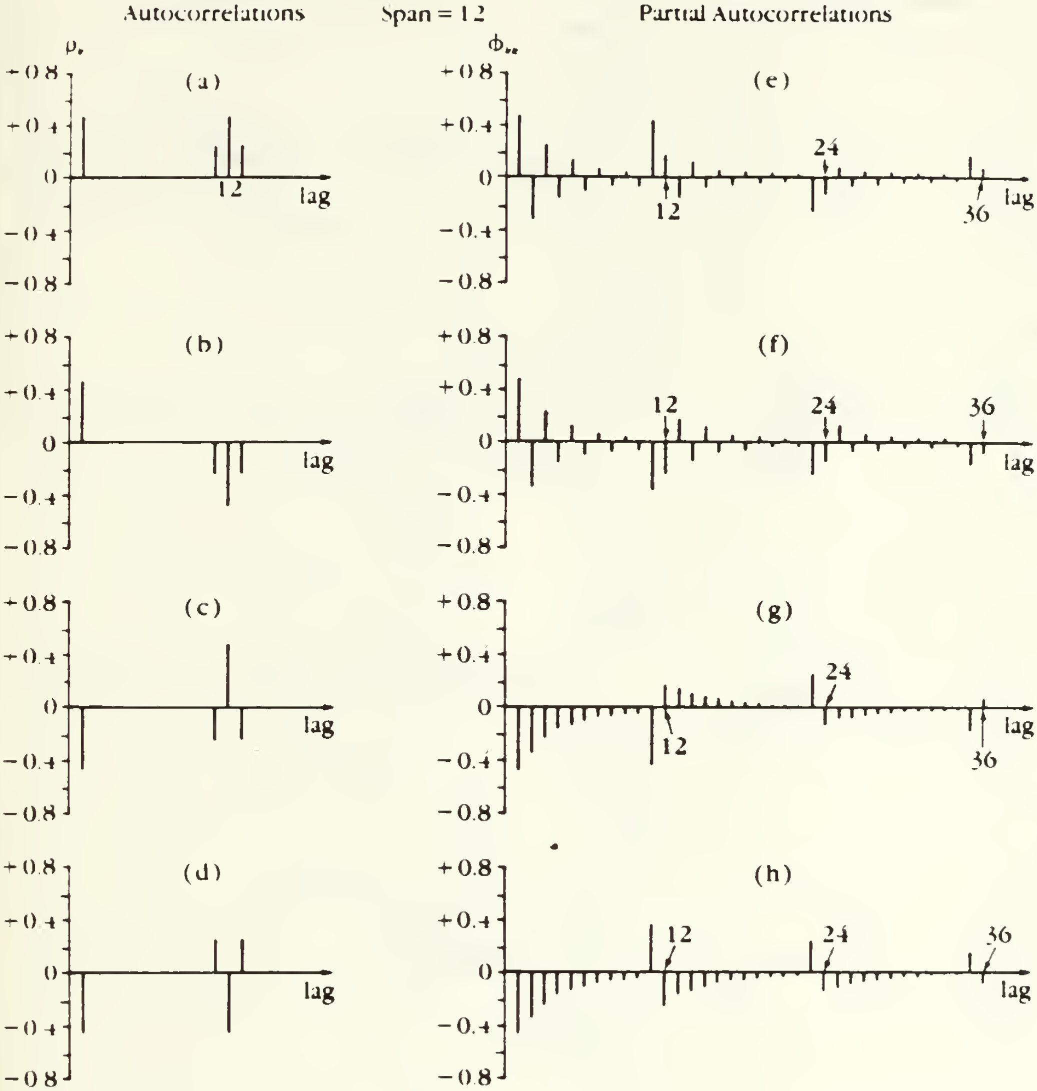

Figure A.12 MA(1) X SMA(1) Seasonal Model ACs and PACs.

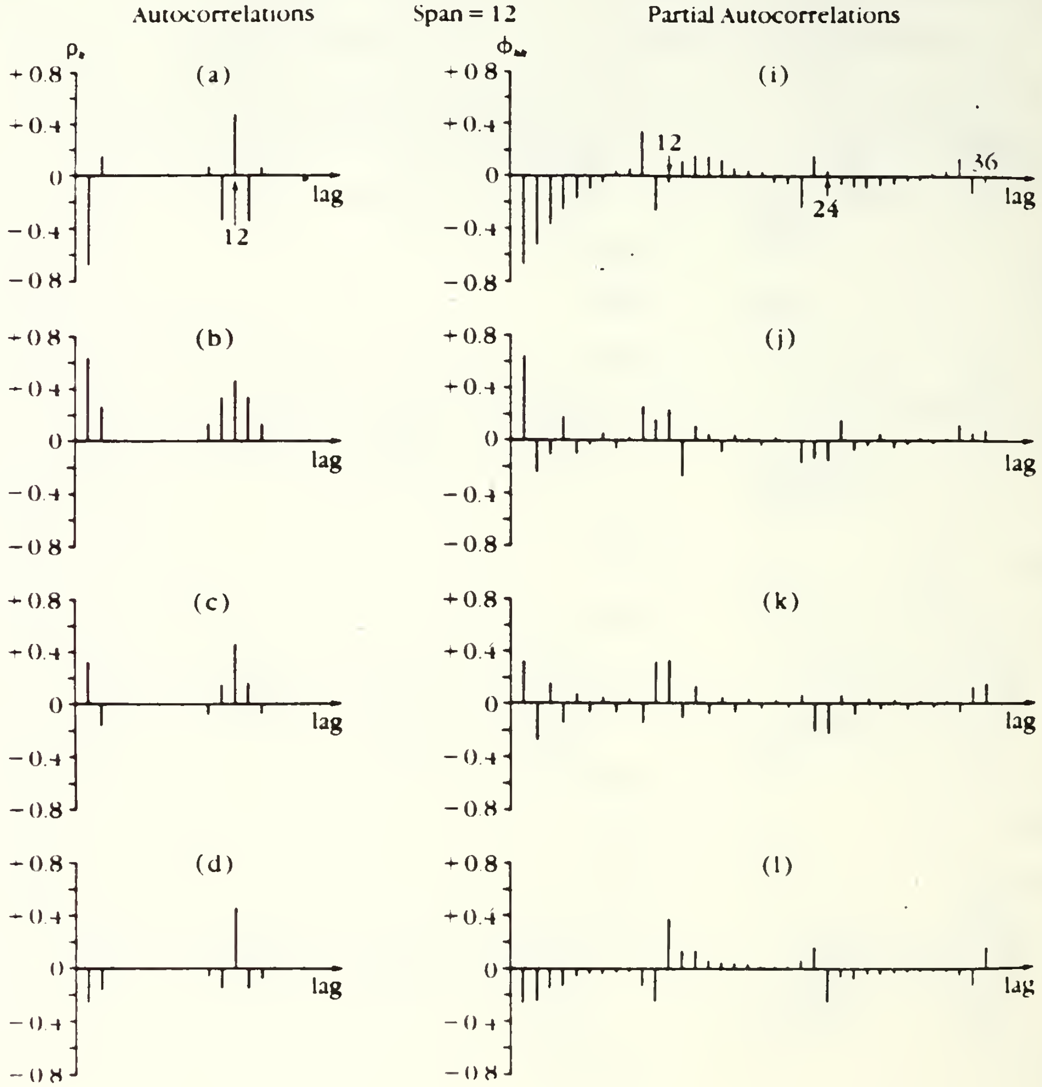

Figure A.13 MA(2) X SMA(1) Seasonal Model ACs and PACs.

# APPENDIX B

## TIME SERIES PLOTS OF THE VARIABLES

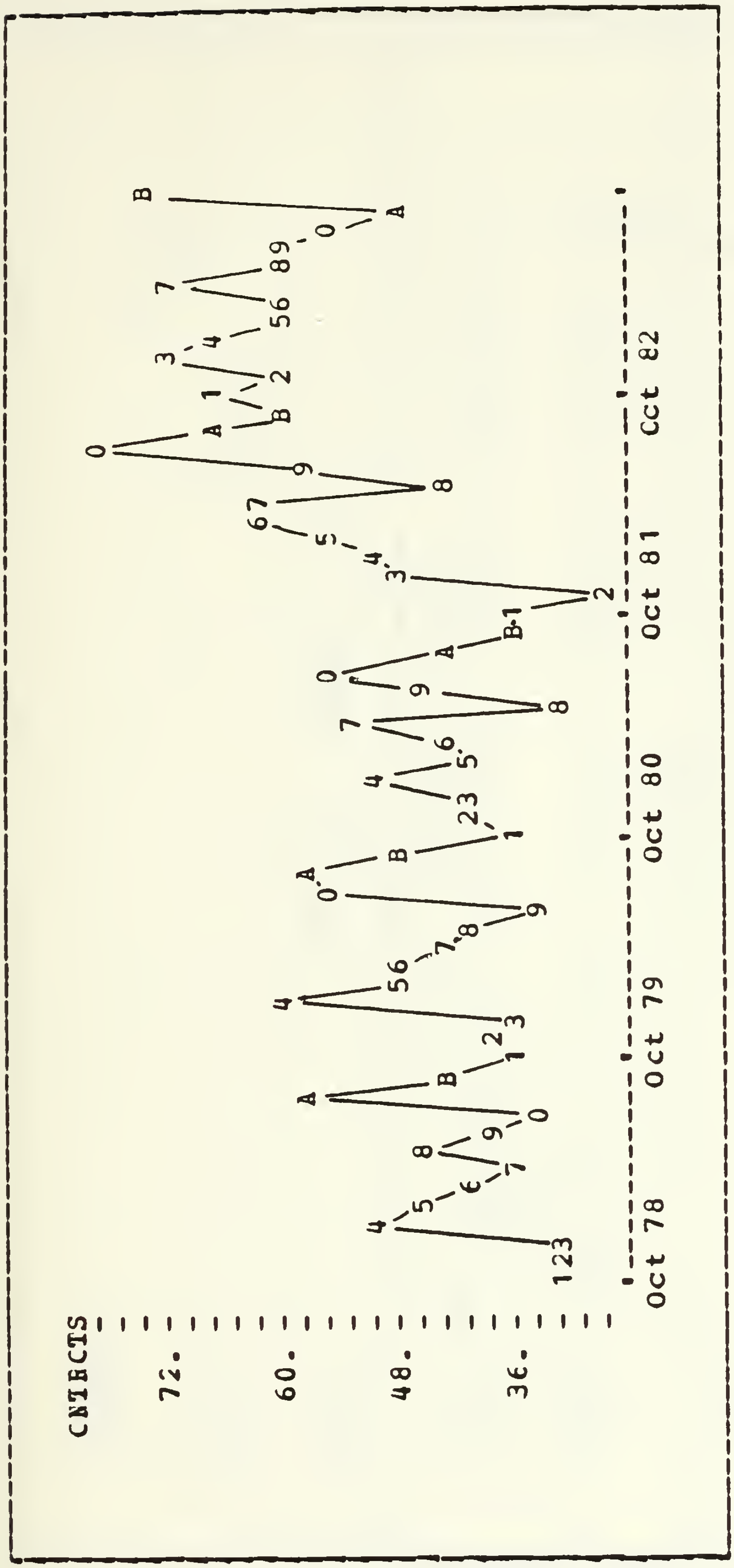

Figure B.1 CNTRCTS.

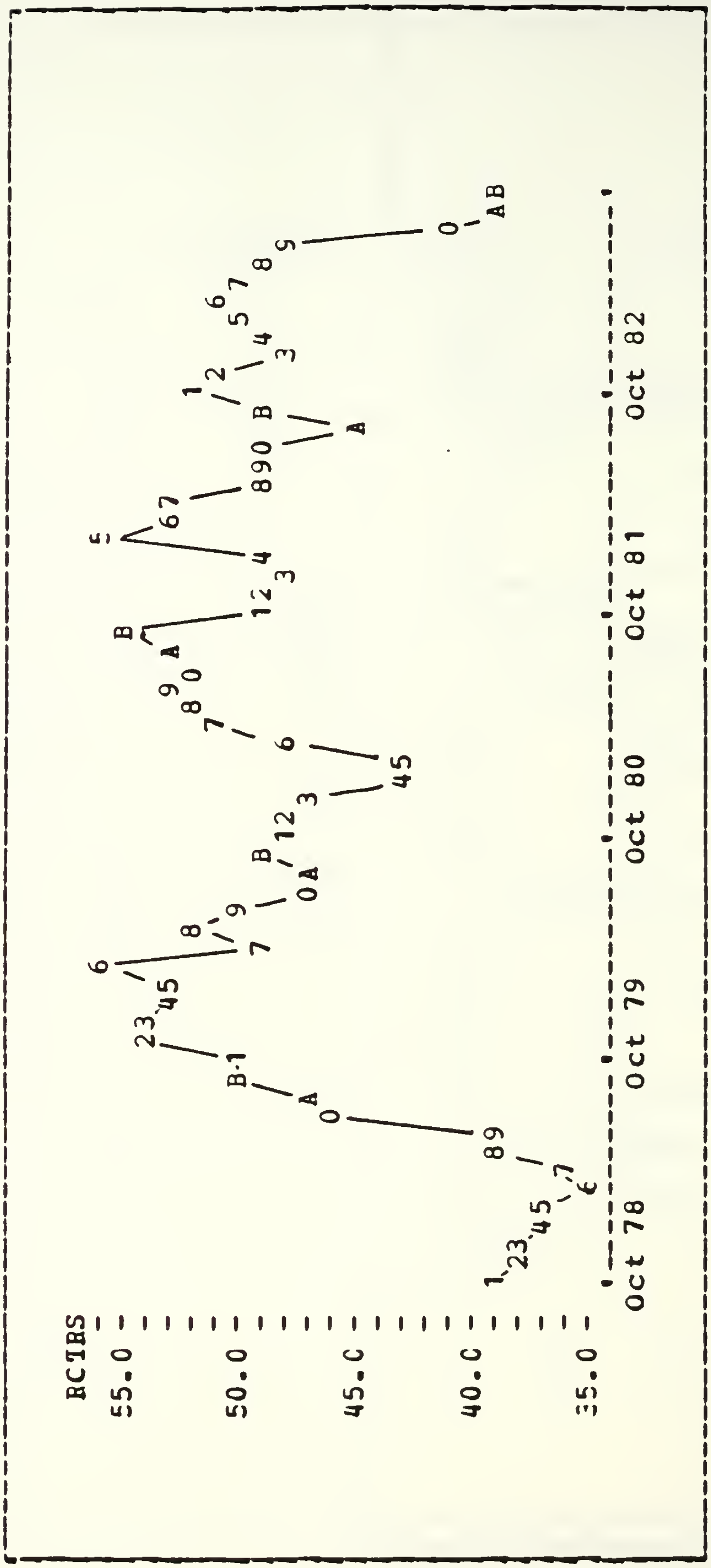

Figure B.2 RCTRS.

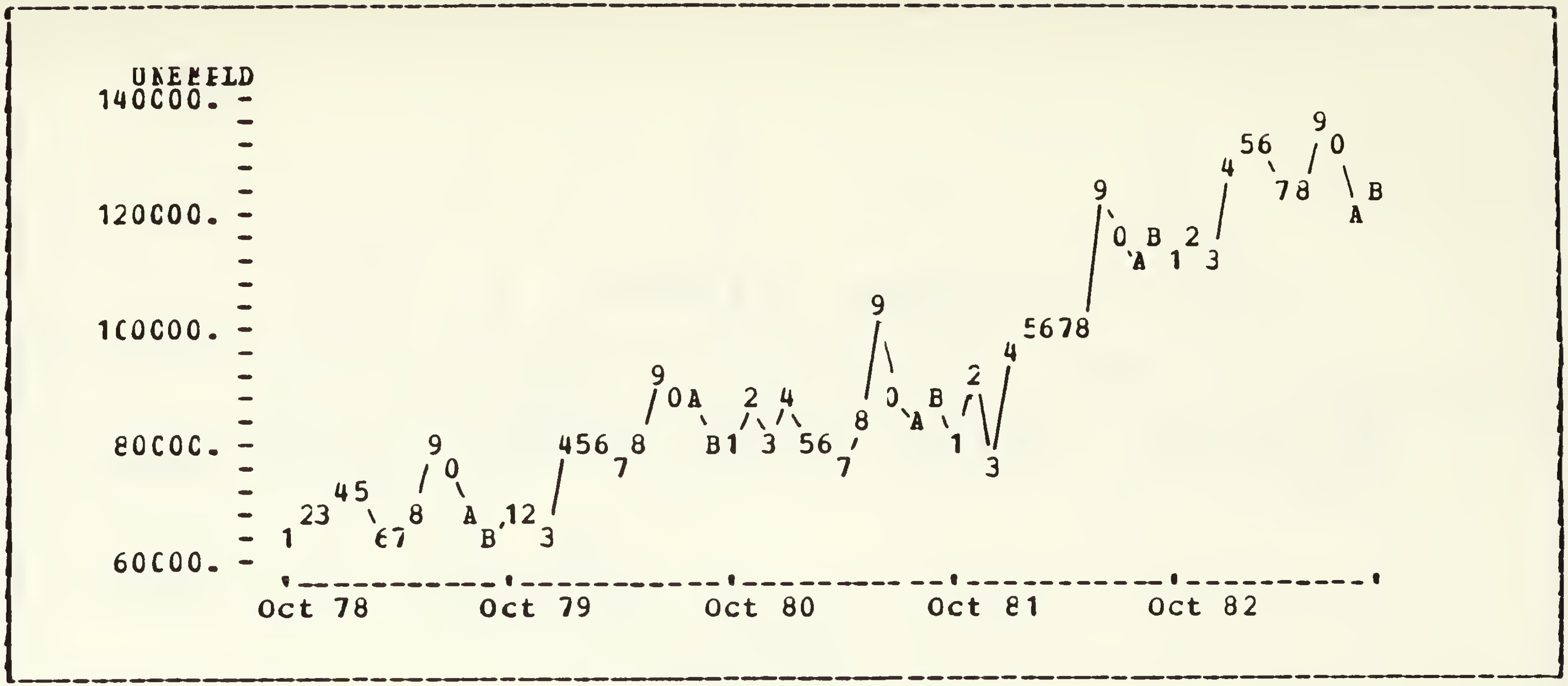

Figure B.3 UNEMPLD.

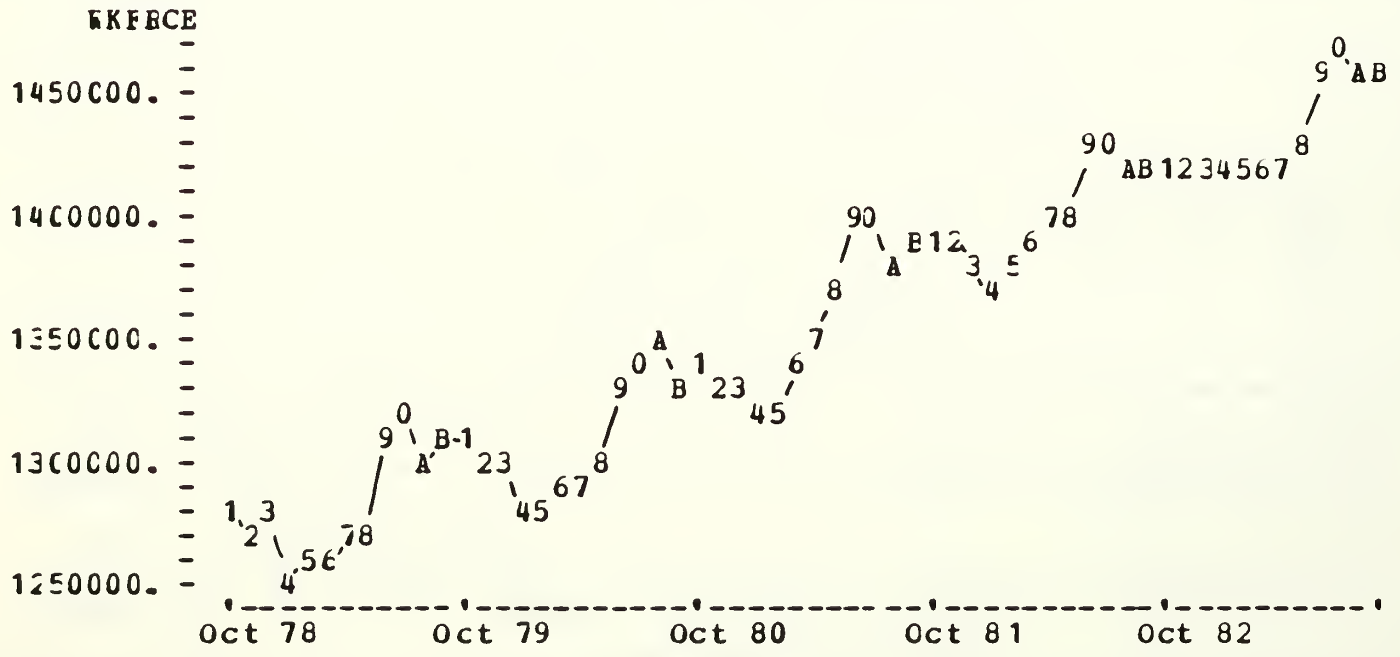

Figure B.4 WKFRCE.

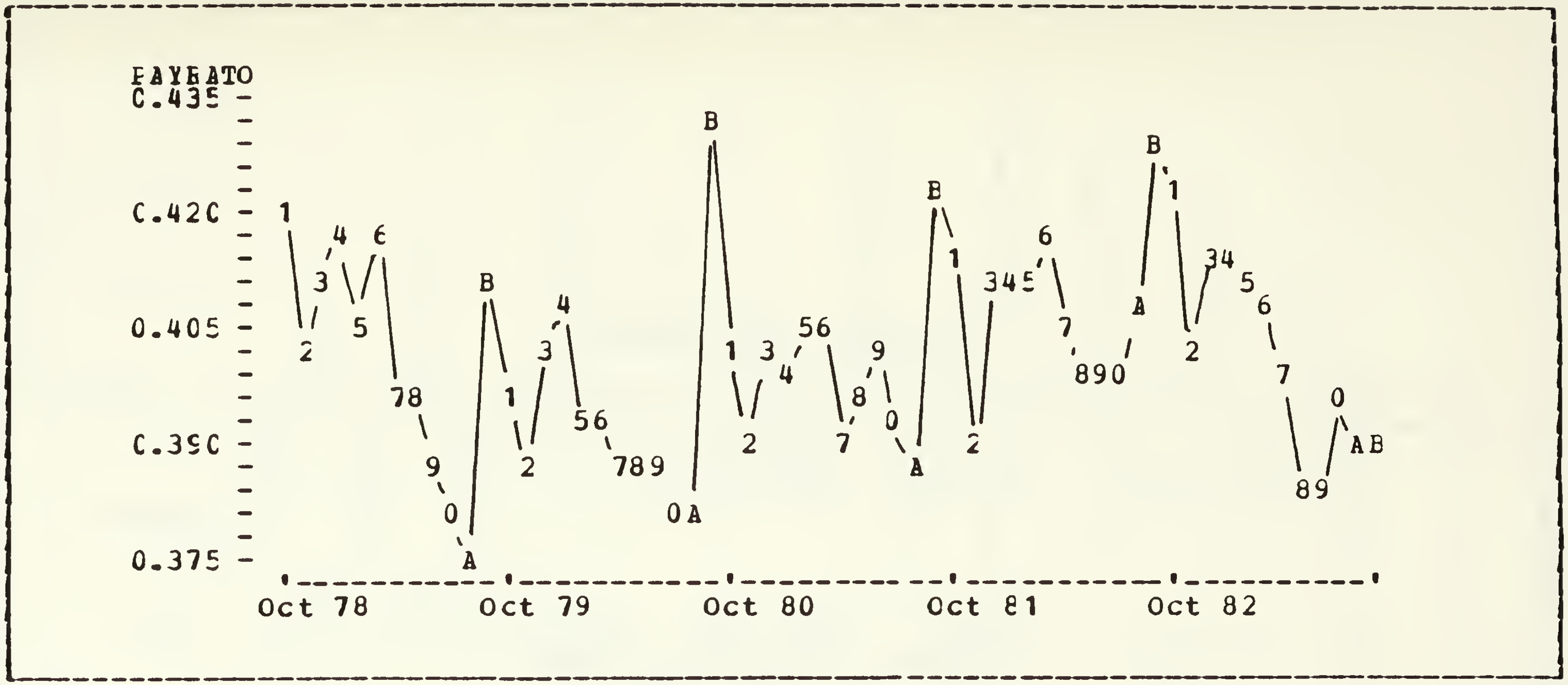

Figure B.5 PAYRATO.

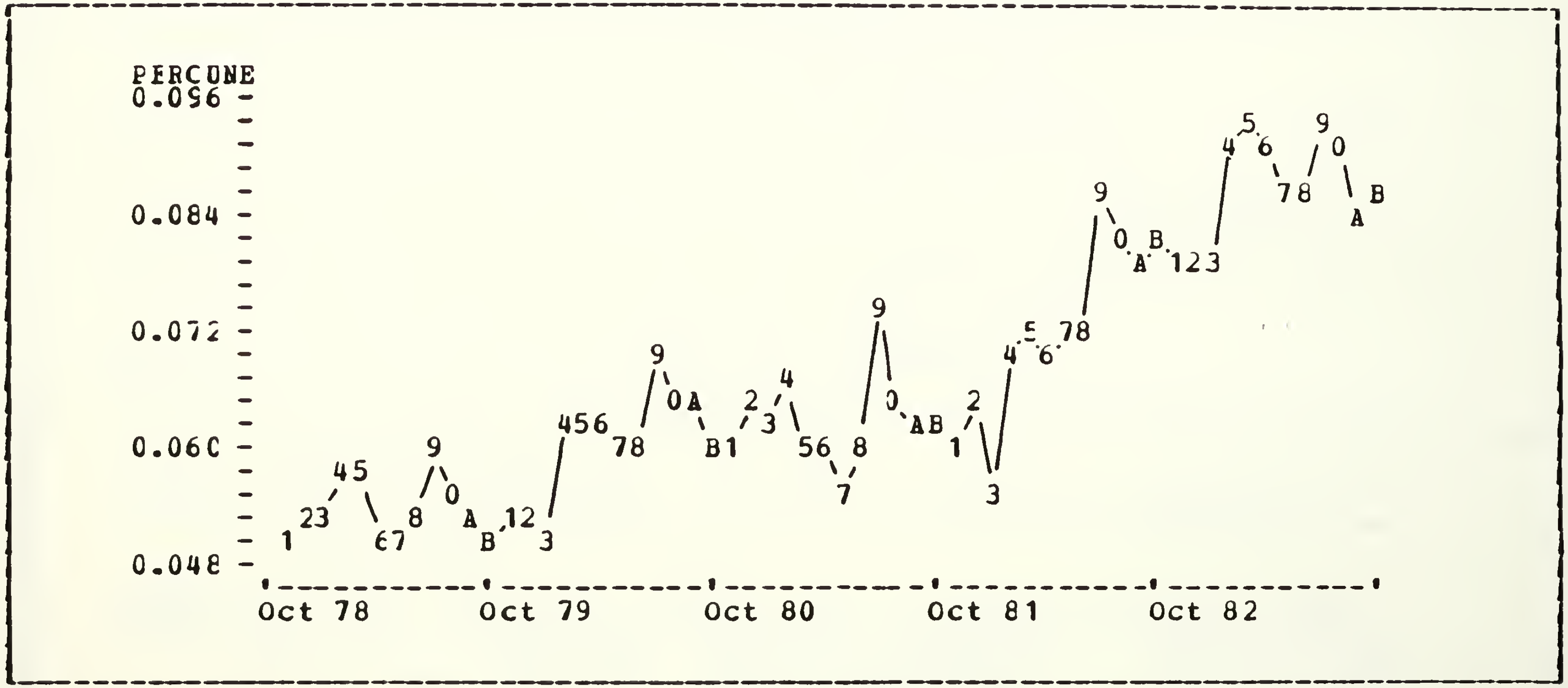

Figure B.6 PERCUNE.

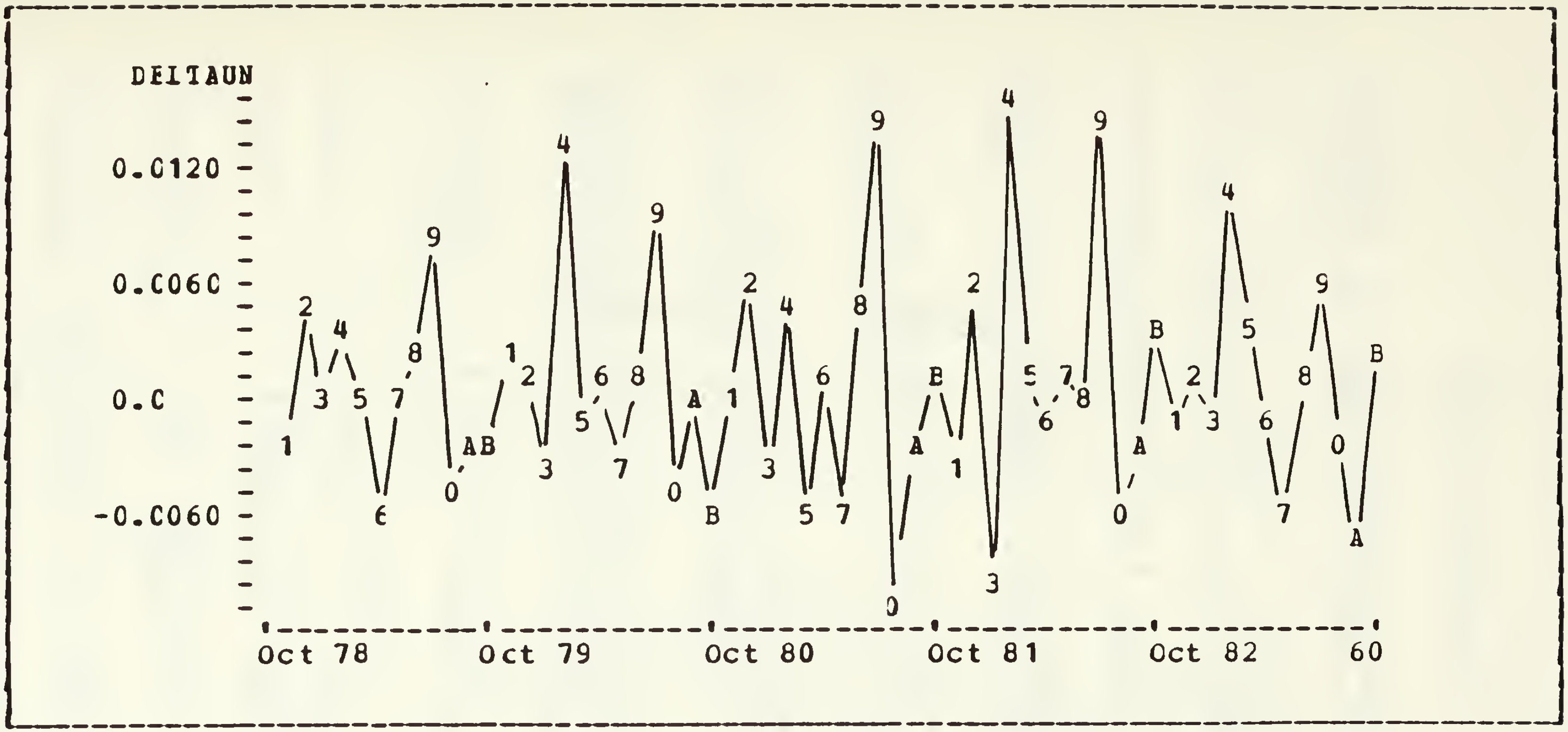

Figure B.7 DELTAUN.

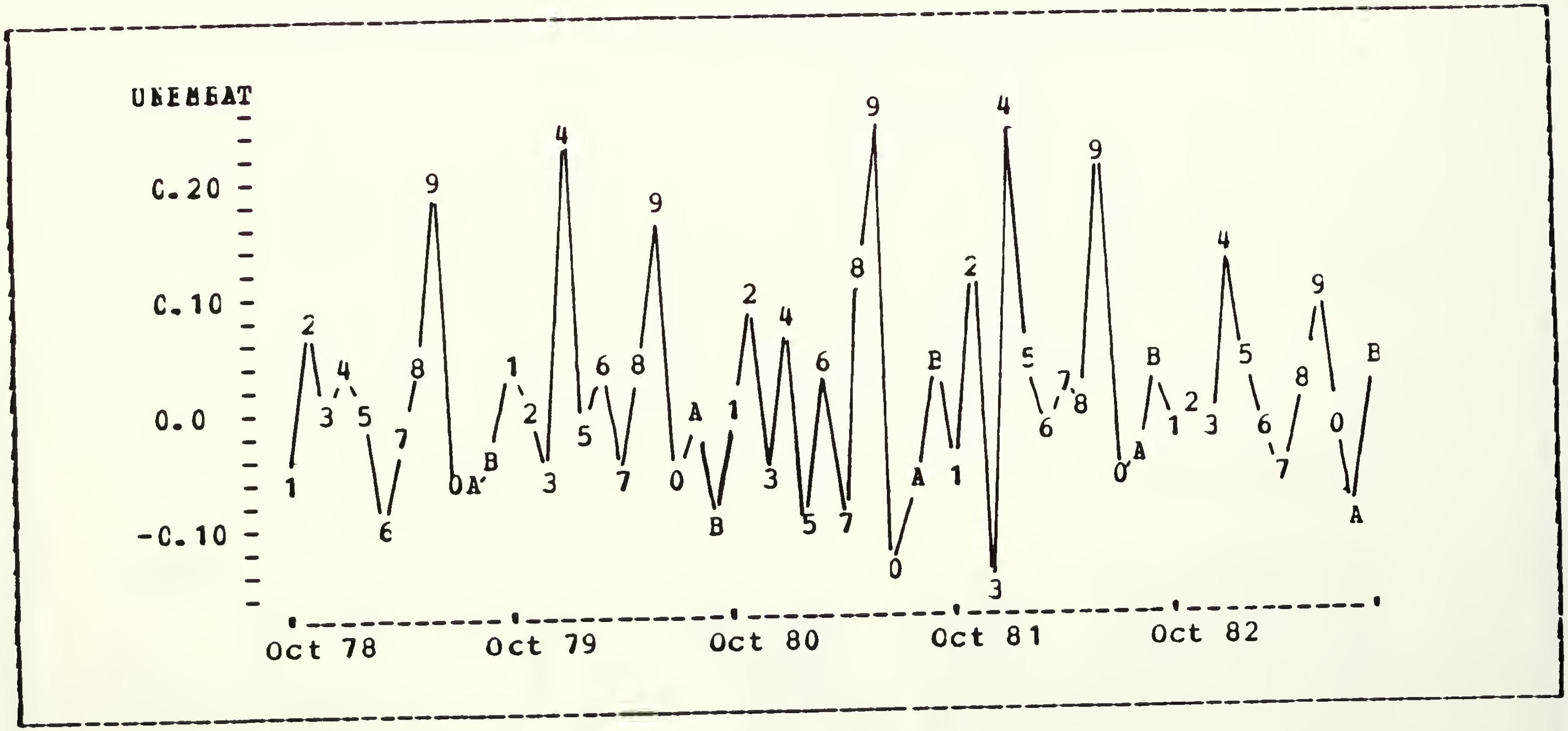

Figure B.8 UNEMRAT.

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